1980-09

An ASW campaign model.

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NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

AN ASW CAMPAIGN MODEL

by

Mark Douglas Frost

September 1980

Thesis Advisor: CAPT W. P. Hughes, USN

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) An ASW Campaign Model		5. TYPE OF REPORT & PERIOD COVERED Master's Thesis; Sep 1980
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Mark Douglas Frost		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940		12. REPORT DATE September 1980
		13. NUMBER OF PAGES 121
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) Naval Postgraduate School Monterey, California 93940		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Anti-submarine warfare, ASW, ASW campaign, ASW model, campaign model, Naval campaign, Naval model

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

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(Page 1) S/N 0102-014-6601

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

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An ASW Campaign Model

by

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Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN OPERATIONS RESEARCH

from the

NAVAL POSTGRADUATE SCHOOL
September 1980

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ACKNOWLEDGEMENT

The author takes great pleasure in acknowledging those individuals that made it possible to bring this thesis into being. These especially include CDR John G. Burton, USN, who encouraged and fostered the author's efforts in this direction, and CDR Charles Hall, USN (Ret.), who further guided the development of this model. Appreciation is expressed to CAPT Wayne Hughes, USN, who gave so freely of his time and ideas. Finally, the author thanks his wife, Paula Jean, for her encouragement and understanding in allowing her husband to devote so much of his time that really belonged to her on this effort.

I. INTRODUCTION

The Office of the Chief of Naval Operations, in conducting the Planning, Programming, and Budgeting process, must procure, maintain, and operate an exceptionally capable antisubmarine warfare force to counter the Soviet submarine fleet. Extensive analysis of naval experience and detailed modeling of such conflict is employed toward that end.

As an aid to the naval decision-maker, a large-scale, aggregated, highly flexible model of the ASW campaign is hereby offered to enhance insight into a war at sea.

Specific objectives of the model evolved during the development of the current ASW CPAM (CNO Program Analysis Memorandum). To assess the adequacy of current naval force levels and asset balance, a flexible, but simple, fast-running computer analysis of the ASW campaign was deemed necessary. The model was designed, first and foremost, to examine the change in the marginal effectiveness of friendly ASW forces due to changes of force level, force mix, and force employment strategies.

To meet the objectives, an hierarchical approach was taken that would employ the outputs of detailed battle, or engagement, models to generate inputs to an easily-understood and deterministic campaign model. The complexity of a war at sea is recognized; however, for computational clarity, an expected-value model has been used. Application of a deterministic model of attrition is widely accepted in lieu of stochastic simulation [TAYLOR, J.G. 1980].

The campaign model has been programmed in the APL/360 language for use on an IBM 360/67 computer. Execution of a thirty day ASW campaign in which five types of each defined platform or force interact within ten ocean areas requires less than ten minutes of CPU time.

The model is keyed to the interaction of the threat submarine force with friendly ASW forces and merchant or military shipping. Specific features of the campaign model provide for:

1. Threat deployment options; threat submarines may be deployed to any ocean area via any specified route. Cycle definition is flexible, as is time-phasing of the deployments. The model allows tasking of the threat submarines against four primary target types: independent shipping,convoys, underway replenishment groups, and battlegroups.

2. Allocation of friendly forces; the model takes as user inputs the allocation of friendly assets consisting of attack submarines, maritime patrol aircraft, and surface escorts, with or without embarked helicopters. Such assets may be employed in area or barrier search, or in direct support. Tasking of ASW forces is to some extent controllable; ocean area assignments may be absolute, or implicit via a specified track. Minefields may be placed within any ocean area on any schedule.

3. Attrition to threat and friendly forces; present campaign models generally do not account for the reduction of ASW effectiveness resulting from losses to friendly force levels during the campaign, reducing only threat submarine quantities. This model attrits both sides by an easily understood process.

4. Aggregation of friendly ASW force performance; friendly forces in direct support (of a convoy, URG, or battle group) are aggregated to

provide a combined effectiveness against the attacking threat submarine. Any number of friendly assets of varying types may be employed within any specified ocean area. The sequence of platform (that is, attack submarine, maritime patrol aircraft, and so forth) interactions with the threat force is determined by the user.

Undersea surveillance systems may provide submarine probability areas (SPAs) for prosecution by maritime patrol aircraft; such surveillance systems may be programmed to become inoperative at a specified time to reflect loss of same.

Submarine datums for prosecution by maritime patrol aircraft will result from interaction between independent shipping and threat submarines.

5. Sensitivity to force levels; attrition of threat submarines is sensitive to both quantities (within an ocean area) of threat submarines and friendly forces present, as is the attrition of friendly platforms.

The effectiveness of each minefield is sensitive to the quantities of mines present.

6. Parametric treatment of other warfare area effectiveness; a naval campaign includes significant interaction other than the antisubmarine warfare. Any campaign analysis must recognize such other attrition to forces to yield realistic conclusions. Attrition to all forces is treated parametrically, specific to each area and platform type. Decay of force levels due any other cause (for example, increased tempo of operations, logistics difficulties) may be introduced through the same parametric inputs.

7. Deployment of submarines within "wolfpacks", and coordinated barrier stations; both threat, and friendly, submarines may be deployed

to operate independently or in coordination within a wolfpack or barrier station of homogeneous submarines. Upon attrition to a wolfpack or barrier, submarine performance parameters are changed appropriately.

II. THE CAMPAIGN MODEL

The campaign determines the results of the large numbers of interactions between threat submarines, friendly antisubmarine warfare forces, and merchant shipping. Friendly ASW forces include attack submarines, maritime patrol aircraft, surface escorts, and mines. Such forces (mines excepted) may be employed in direct support of underway replenishment groups and battle groups which may also interact with the threat submarine force. Merchant shipping may sail either independently or in protected convoys.

Interactions take place on a daily basis, a time step deemed adequately brief to capture the campaign dynamics, yet provide a fast-running computer model. Consequently, parametric inputs are defined for a daily occurrence; availability of such data also favors usage of the time step of one day.

On each day of the campaign, forces within each ocean area interact and outcomes are determined in accordance with the specified sequence of engagements. Such outcomes are valid only to the extent that the assumptions of the model, and the tactics and strategy implied, hold to be true.

Movement of each platform along a specified track is effected prior to any daily interaction. Each platform, in general, proceeds in accordance with a programmed cycle. Elements may be initialized on D-Day at any stage of the cycle, or introduced into the campaign via the deployment schedule. Exceptions to such actions are maritime patrol

aircraft, and mines; specified quantities of each are assigned to each ocean area at the outset.

In preparation of input, careful consideration must be given to determination of ocean areas. Any number of ocean areas, of any geographic size, may be defined. An ocean area may be thought of as a "box" in and out of which threat and friendly forces move and interact. Such areas may be established for several reasons; a primary factor to be considered is the varying oceanographic effect on parameters such as a probability of detection. Tactics employed may determine the size and quantity of ocean areas; for example, each barrier may require definition of the encompassing waters. The radius of action for any platform is implicity assumed to be that ocean area to which the unit is assigned for a given day. An area may, and more often than not will, exceed a platform's radius of action; but, a platform may not interact with forces outside of its assigned area. Specification of ocean areas must be sufficient to encompass intended tracks for all forces. Care must be taken to specify inputs that account for maritime patrol aircraft and submarine transit times, operating ranges, maintenance time, and in-port turnaround time for surface forces.

For any platform (such as threat submarine or maritime patrol aircraft), any number of different types (within reasonable limits to avoid excessive APL workspace size or CPU time requirements) may be specified. The model does not limit the user to one or two or even several types within a platform (as is often the rule). Definition of different types of platform may be required for several reasons in addition to fleet classifications (such as a Charlie class Soviet submarine, or a P-3C

Update II aircraft). Each fleet class requires a type designation within the model to reflect differences in utilization schedules, performance values, and weapon capabilities. Since each type defined proceeds in accordance with a specified track, a type must be created for each track desired; (ocean area assignments and cycle definitions are implicit within a specified track).

A key feature of APL, the computer programming language employed for the model, allows the user to interact with the model at any stage of the campaign; at such times, parameters or force levels may be altered, elements may be reassigned, or simply the results of interaction examined. The flexibility offered may prove invaluable to the decision-maker in the evaluation and restructure of a campaign.

Two general approaches are utilized to determine the outcome of interaction between friendly forces and threat submarines. Either approach necessitates assumption of an offensive, and defensive, force. The offense initiates an engagement, while the defense may counterattack but otherwise seeks to avoid any contact. Friendly ASW forces operating in barrier or area search assume an offensive role; the threat submarine becomes the offensive platform when attacking shipping, underway replenishment groups, or battle groups.

The outcome of an interaction between opposing single units (for example, prosecution of a threat submarine by a maritime patrol aircraft) is determined in a deterministic manner. The basic assumption, common to ASW analysis, is that elements operate independently, and engage at most one target at any time.

The second approach, used for engagements with convoys, URGs, and

battlegroups, employs a firepower index to aggregate the ASW effectiveness of heterogenous platforms within the engaged element. Expected attrition to each platform is explicitly specified.

Specific APL functions (within APL, any "program" or "subroutine" is created as a "function") model the pairwise interaction between platforms, such as between maritime patrol aircraft and threat submarines. The basic approach is, for the most part, applicable to each function; any deviations peculiar to a platform are explained in the applicable platform description.

A. INTERACTION BETWEEN INDIVIDUAL ELEMENTS

Quantities of each platform within a given ocean area are first ascertained; only those offensive elements that are specifically tasked against the defensive platform and have weapons remaining may engage targets.

The offensive platform initiates engagements given the opportunity via the parameter "probability of detection". Every defensive element within the area is a target of opportunity during a given day. "Probability of detection" is defined to be: the probability of detection, classification, localization, and closure to attack range given an opportunity. (NOTE: probability of attack is included within the defined probability of detection. Such probability of attack is more often included in the parameter probability of kill given detection. Inclusion of the probability of attack within the probability of detection is essential to the model computations.) The parameter, probability of detection, is specific for each ocean area, each offensive platform type, and each defensive platform type.

The probability of detection for an area must implicitly reflect the offensive tactics employed, such as area search or open-ocean barrier, as well as the geographic size of the ocean area. Such factors are often expressed within the coverage factor. Within the model, the probability of detection, and the probability of kill given detection, are to be defined for one offensive element interacting with one defensive element within the daily time step.

Each offensive element is limited to a specified number of engagements (attacks on targets) per daily time step. The parameter is specific for the offensive platform type (such as class threat submarine) and defensive platform (such as independent ship but not type independent ship). A common assumption in Navy campaign analyses permits but one engagement per day for most platforms; such need not be assumed nor be appropriate. The actual limit on engagements is largely a function of the time required for prosecution of a target. Other factors, such as inoperability and repair functions, or strategy, may decrease the rate of engagement.

Given detection and attack, defensive platform attrition is determined by the parameter probability of kill (given an attack). (NOTE: the probability of kill does not include the probability of attack as is common procedure.) The probability of kill is specific to each ocean area, each offensive platform type, each defensive platform type, and implicitly includes all reattacks on the same defensive platform. Additionally, the parameter is dependent upon the number of weapons expended as specified for each attack; (the type of weapons expended is a function of each platform type).

If a defensive platform is engaged, it may then counterattack. No limit is imposed on the number of counterattacks by an element, that is, within the time step and function. The combined probability of a counterattack and kill is defined as the parameter probability of kill. (NOTE: probability of kill is defined differently for an offensive element than for a defensive element.) The counterattack probability of kill is specific for each ocean area, each defensive platform type, and each offensive platform type. This parameter, as an attack probability of kill, is dependent upon the number of weapons expended for each (counter) attack.

Inventories of remaining weapons are maintained in the model only for threat submarines and friendly attack submarines. Given the number of attacks by an element, the corresponding inventory of weapons is reduced in accordance with the specified number of weapons expended for each attack. These weapons are also reduced proportionate to element attrition.

Computations in accordance with the preceding description proceed as follows. (NOTE: abbreviations used within this section are for illustration only; function variable names are in accordance with Appendix A.)

References to elements, or types of elements, are applicable to the two platforms interacting within each APL function.

Total attrition to the defensive elements of each type due to all offensive elements is first computed. Each pairwise engagement is assumed to occur as a Bernoulli event; total attrition to each element then assumes a Binomial distribution. Total attrition to each type of defensive

element is computed as:

$$ATTRIT(J)=DEF(J)\times(1-\underset{\text{all } I}{\times/}(1-PD(IJ)\times PK(IJ))*OFF(I))$$

WHERE:

ATTRIT(J): Attrition to elements of type J of the defensive platform due all elements of the offensive platform.

DEF(J): Number of elements of type J of the defensive platform.

PD(IJ): Probability of detection; detection of an element of type J of the defensive platform by an element of type I of the offensive platform.

PK(IJ): Probability of kill given detection; attack of an element of type J of the defensive platform by an element of type I of the offensive platform.

OFF(I): Number of elements of type I of the offensive platform.

x/: Product of the elements.

*: Exponentiation.

This computation provides an upper bound on the attrition to the defensive elements; if the probability of detection is "small", the expected attrition will be closely approximated by this bound. (See Appendix C.)

Given total attrition to the defensive elements, each type of offensive element is assumed to have inflicted such losses in accordance with the total probability of kill for each type (through an application of Bayes' Theorem). Total attrition to each type of defensive element due to each type of offensive element is computed as:

$$ATTRIT(IJ)=ATTRIT(J)\times\frac{(1-(1-PD(IJ)\times PK(IJ))*OFF(I))}{(\underset{\text{all } I}{+/}(1-(1-PD(IJ)\times PK(IJ))*OFF(I))}$$

where:

ATTRIT(IJ): Attrition to elements of type J of the defensive platform due elements of type I of the offensive platform.

+/: Sum of the elements.

If attacks are independent and each probability of kill has the same value for each attack, then the number of the attacks to the first success (attrition of target) will have a geometric distribution. The mean, or the expected number of attacks to obtain attrition of the target, is therefore the reciprocal of the probability of kill.

Consequently, the number of attacks on each type of defensive element by each type of offensive element may be determined and any appropriate constraint on such engagements per day applied. Any daily limit to the number of engagements for each offensive element is applied by constraining the total attacks on all defensive elements.

If this engagement limit is an operative constraint, the number of defensive elements attrited is reduced accordingly:

REDUCED ATTRIT(IJ) =

$$\mathrm{ATTRIT(IJ)} \times \frac{1}{\mathrm{PK(IJ)}} \times \frac{\mathrm{Min}\left(\underset{\text{all J}}{+/}\left(\mathrm{ATTRIT(IJ)} \times \frac{1}{\mathrm{PK(IJ)}}\right);\mathrm{OFF(I)} \times \mathrm{ENG(I)}\right)}{\underset{\text{all J}}{+/}\left(\mathrm{ATTRIT(IJ)} \times \frac{1}{\mathrm{PK(IJ)}}\right)}$$

where:

ENG(I): Maximum number of elements of the defensive platform that may be engaged per day by each element of type I of the offensive platform.

Weapon inventories of offensive elements are reduced for each attack on defensive elements. (NOTE: weapon inventories are maintained only

for threat and attack submarines.) Weapons expended by each type of offensive element against each type of defensive element is computed as:

$$WPN(IJ) \times \frac{1}{PK(IJ)} \times ATTRIT(IJ)$$

where:

WPN(IJ): Number of weapons expended per attack on an element of type J of the defensive platform by an element of type I of the offensive platform.

Accounting is maintained of any weapons, for each type of weapon, expended in excess of those carried by each type of submarine. Within a daily time step, no limit is imposed on the attacks by a submarine as a result of expending all remaining weapons. Any attempt to do so would require adjustment of the corresponding parameter probability of kill; such adjustment would be complex because the probability of kill may be a non-linear function of the number of weapons expended. It was deemed sufficient to keep an accounting of excess weapon expenditure as a simple check on the frequency that "overexpenditure" occurs.

Given the number of engagements for each offensive element, their attrition due to all defensive elements is computed. To avoid attrition, an offensive element must survive all counterattacks. Total attrition to each type of offensive element is computed as:

$$OFF(I) \times (1 - \underset{\text{all } J}{x} / (1 - PK(JI)) * ((\frac{1}{PK(IJ)} \times ATTRIT(IJ)) / OFF(I)))$$

where:

PK(JI): Probability of kill; counterattack on an element of type I of the offensive platform by an element of type J of the defensive platform.

This computation provides an upper bound on the attrition to the offensive elements; if the probability of kill is "small", the expected attrition will be closely approximated by this bound. (See Appendix C.) Computations proceed in the same manner as for attrition to the defensive elements. Any defensive element will successfully counterattack, if engaged, with a specified probability of kill.

Remaining inventories of weapons are then reduced proportionate to element attrition.

B. INTERACTION BETWEEN A THREAT SUBMARINE AND A PROTECTED FORCE

Within each of the three functions applicable to the protected forces (CONVOY, UNREGROUP, BATTLEGROUP) an identical model interaction is employed. Firepower indices are utilized to aggregate the ASW effectiveness of all screening elements (nominally maritime patrol aircraft, attack submarines, and surface escorts) and losses to the protected platforms (for example, merchant ships within a convoy) are determined.

Each protected force (which includes the screening and protected elements) is treated as a unit at all times. A fractional convoy does not exist; a convoy either exists or it is totally eliminated. A convoy exists if there are merchant ships; an underway replenishment group exists if there are auxiliary ships; and a battle group exists if there are aircraft carriers. Without such elements present, ASW elements are assumed to be dispersed for other tasking, and there can be no more interactions.

Screening elements, once assigned to a force, are assumed to transit with the same force throughout the specified force cycle. If only

area assignment of the screening platforms is desired, elements may be allocated via the appropriate platform cycle or area assignment.

Weapon inventories are not maintained for (friendly) protected forces. Cautiously, such elements are assumed not to be weapon limited; to some extent, the assumption depends upon survival of the underway replenishment groups. This critical aspect should be further examined.

Quantities of each force within a given area are first ascertained. Only those threat submarines that are specifically tasked against the protected force and are weapon capable may engage targets. Any protected force within the ocean area in question may be engaged.

The threat submarine is assumed to engage the protected force according to the parameter, probability of engagement. Every protected force within the area is a target of opportunity during a given day.

Probability of engagement is defined to be: the probability of detection, localization, and closure to engage a force given the opportunity. The probability of attack may, or may not, be included in such definition as desired; inclusion, or omission, of same should be consistant with the parameter "expected loss" per engagement. The parameter "probability of engagement" is specific for each ocean area, each type of threat submarine, and each type of protected force (for example, convoy with military cargo).

The probability of engagement within an area implicitly reflects the tactics employed by both the threat submarine (for example, barrier within a SLOC), its weapons (for example, missiles or torpedoes), and the protected force (type formation, for instance). Within the model, the probability of engagement parameter is to be defined as that for one

threat submarine, or "wolfpack", interacting with one protected force within the daily time step.

Each threat submarine is limited to a specified number of engagements per daily time step. The parameter is specific for the type of threat submarine and protected force engaged. The actual limit on engagements is largely a function of the time required per protected force engaged. A common assumption within Navy campaign analyses permits but one, or possibly two, engagements per patrol cycle against any protected force; within such engagements, threat submarines often are assumed to expend all available weapons against the force. An appropriate assumption, or other constraint due weapon limitations, may establish an upper bound on the daily engagement limit.

Given an engagement, attrition to the elements within the protected force, attrition to the threat submarine, and weapons expended by the threat submarine are defined by the parameter "expected loss" per engagement. These values for each screening platform, the protected platform, the threat submarine, and the weapons expended, are specific for each pairwise interaction (that is, type of threat submarine, and type of protected force). Expected losses are not specified as a function of ocean area (though probability of engagement is so defined).

The expected loss to each battle group, underway replenishment group, or convoy component, and to the attacking submarine, are adjusted as a function of the current remaining ASW effectiveness of the protected force. Each element of each screen, and each protected element (if applicable), is weighted by an ASW firepower score; such scores are

aggregated over all elements within a force to yield the corresponding ASW firepower index for the force. The current firepower index is then compared to an original (full strength) reference firepower index (that ASW effectiveness for which the parameter "expected loss" per engagement is specified) to establish the current remaining ASW effectiveness of the force as a fraction of the original effectiveness.

An expected loss curve is specified for each platform as a function of the relative ASW effectiveness of the force via the two parameters: expected loss per engagement (reference value) and an exponent, both unique to each pairwise interaction. An exponent is applied to the relative ASW firepower index (fraction of reference firepower index) to determine the current attrition for each engagement (as a fraction of reference expected loss) to each platform. Examples of such loss curves are provided (Figure 1; Figure 2). If attrition to a platform decreases with a reduction in the ASW effectiveness of the protected force (such as attrition to a threat submarine), a positive exponent of value less than one should be appropriately chosen. If attrition to a platform increases with a reduction in the ASW effectiveness of the protected force (for example, attrition to the merchant ships within a convoy), a negative exponent should be chosen.

Threat submarines may employ either conventional torpedoes or missiles to attack a protected force. The number of weapons remaining after each engagement will be determined as before.

Inventories of remaining threat submarine weapons are also reduced proportionate to element attrition.

Computations in accordance with the preceding description proceed as follows. (NOTE: abbreviations used within this section are for

illustration only; function variable names are in accordance with Appendix A.)

The number of engagements by each type of threat submarine are first computed. Threat submarines are, in general, not assumed to be target limited; the number of targets of opportunity is assumed to be not small (relative to the number of threat submarines). The forces engaged by each submarine of type I is:

$$\text{ENGPERSUB(I)} = \underset{\text{all J}}{+/}(\text{PE(IJ)} \times \text{FORCE(J)})$$

where:

ENGPERSUB(I): Number of forces engaged per threat sub of type I.

FORCE(J): Number of forces of type J.

PE(IJ): Probability of engagement; engagement of a force of type J by a threat submarine of type I.

Any active constraint on these engagements is then applied over all engagements by each submarine:

Revised ENGPERSUB(I) =

$$\text{Minimum } ((\underset{\text{all J}}{+/}(\text{PE(IJ)} \times \text{FORCE(J)}); \text{ENG(I)})$$

where:

ENG(I): Maximum number of forces engaged per threat submarine of type I.

The number of protected forces of type J engaged by threat submarine of type I is then adjusted accordingly:

$$\text{PE(IJ)} \times \text{FORCE(J)} \times \frac{\text{"Revised" ENGPERSUB(I)}}{\text{"Old" ENGPERSUB(I)}}$$

These engagements are distributed uniformly over the protected forces of type J. This assumes that each protected force is equally

likely to be engaged given an expected number of pairwise engagements (that is, between opposing types).

The current ASW firepower index of each force is ascertained as a percentage of each respective reference ASW firepower index:

$$\text{FPPCT} = \frac{\underset{\text{all K}}{+/}(\text{SCR(JK)} \times \text{FP(JK)})}{\text{REF(J)}}$$

where:

FP(JK): Firepower score per screening element of type K within a force of type J.

FPPCT: Relative firepower index of a force (expressed as a fraction of the reference firepower index).

REF(J): Reference firepower index for a force of type J.

$$\underset{\text{all K}}{+/}(\text{Original SCR(JK)} \times \text{FP(JK)})$$

SCR(JK): Number of screening elements of type K within a force of type J.

The protected platform may contribute to the ASW firepower index as desired or deemed appropriate; for example, an aircraft carrier may enhance the ASW effectiveness of a force, while merchant ships may be but targets.

The aggregated ASW effectiveness of the protected force, in combination with the applicable shape parameter, is applied to compute the attrition to elements of each screen and the protected platform:

LOSS(IJK)x(FPPCT*EXP(IJK))xEngmts by threat sub of type I

where:

EXP(IJK): Shape parameter (exponent) per expected loss curve for screening elements of type K within a force of type J due

a threat submarine of type I.

LOSS(IJK): Expected loss to screening elements of type K within a force of type J due a threat submarine of type I.

and to each type of threat submarine:

LOSS(JI)x(FPPCT*EXP(JI))xEngmts by threat sub of type I

where:

EXP(JI): Shape parameter (exponent) per expected loss curve for threat submarines of type I due a force of type J.

LOSS(JI): Expected loss to a threat submarine, or "wolfpack", of type I due a force of type J.

The number of torpedoes and missiles expended by threat submarines is likewise determined (where the number of weapons expended per engagement is equivalent to the expected loss per engagement). Such weapon expenditure includes all torpedoes and missiles expended throughout the engagement regardless of target.

Remaining inventories of weapons are then reduced proportionate to attrition of the respective threat submarines.

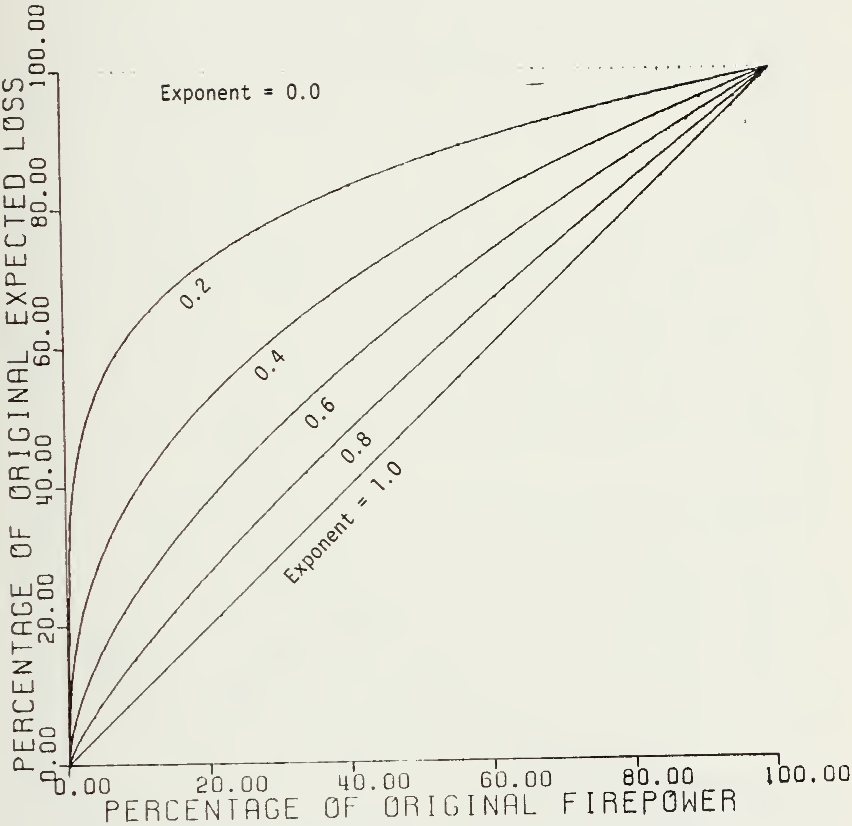
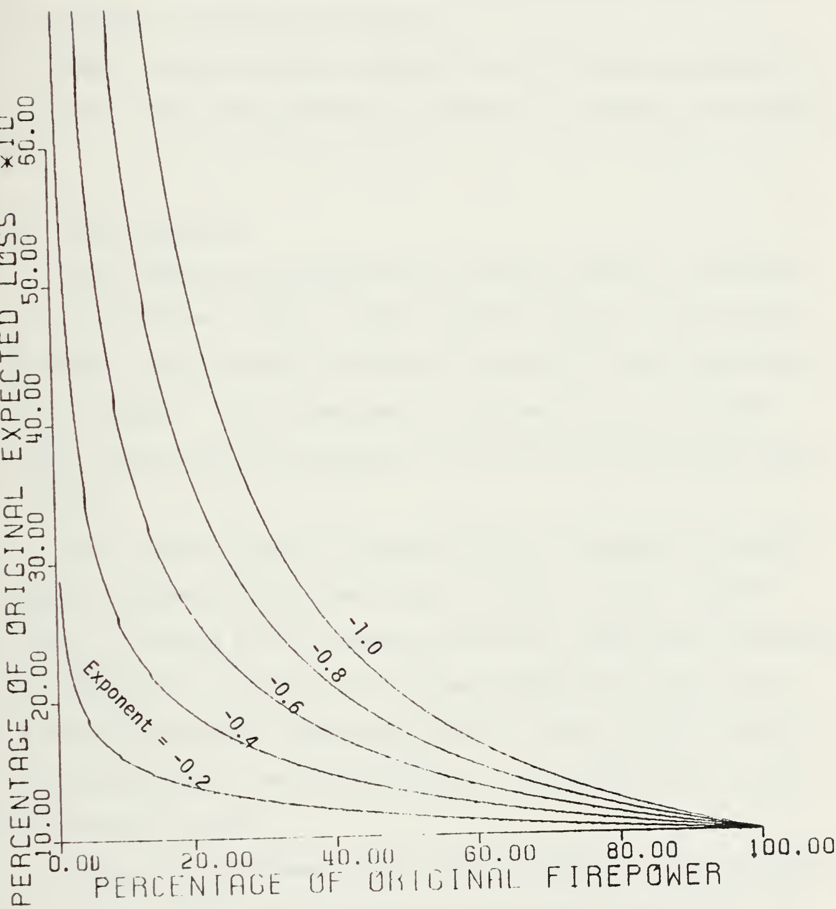

Exponent = 0.0
0.2
0.4
0.6
0.8
Exponent = 1.0
PERCENTAGE OF ØRIGINAL EXPECTED LØSS
0.00
20.00
40.00
60.00
80.00
100.00
PERCENTAGE OF ØRIGINAL FIREPØWER

Figure 1



PERCENTAGE OF ORIGINAL EXPECTED LOSS ×10¹
10.00
20.00
30.00
40.00
50.00
60.00
PERCENTAGE OF ORIGINAL FIREPOWER
0.00
20.00
40.00
60.00
80.00
100.00
Exponent = -0.2
-0.4
-0.6
-0.8
-1.0

Figure 2

III. MISSION ALLOCATION AND PLATFORM INTERACTIONS

Descriptions are provided of each platform, mission allocation, and the specifics of modeled interaction.

Names of input parameters applicable to the following comments are specified. All input parameters are defined in accordance with Appendix A.

A. THREAT SUBMARINE

Threat submarines are defined as all threat submarines, regardless of classification, tasked to attack friendly shipping or naval forces. Strategic submarines may be included if attrition of these submarines is to be computed. Threat submarines are assigned to area or barrier search operations by corresponding track definition and parameter specifications.

Threat submarines may be directed to attack independent shipping, convoys, underway replenishment groups, or battle groups. Specific tasking is defined by the parameters SUBTASKIND, SUBTASKCON, SUBTASKURG, and SUBTASKBG; a percentage of the threat submarines of each type is directed to engage the respective platform or force. Threat submarines may counterattack friendly ASW platforms, but otherwise avoid any contact except as tasked.

Any number of different types of threat submarines may be allocated to area or barrier search operations and deployed to any ocean areas. These different types of submarines must be created to reflect fleet

classification, operational utilization, area of operations, or other considerations. If so desired, a specific type may be created for each threat submarine.

Any employment of threat submarines within "wolfpacks", or coordinated barrier stations, necessitates definition of additional types of submarines. Submarines within each type of "wolfpack" must be homogeneous; or alternatively, parameters specific to a "wolfpack" must adequately describe the (average) performance of each submarine within the "wolfpack".

As the number of threat submarines within a "wolfpack" is reduced (due attrition), the effectiveness of the "wolfpack" is correspondingly diminished. To reflect any change in corresponding parameter values, the remaining submarines may be reclassified as attrition occurs. For example, given an initial "wolfpack" of three submarines, upon attrition of one submarine, the remaining two threat submarines may be reclassified as a different type of "wolfpack" of two submarines. Further attrition to the "wolfpack" may result in a sole surviving threat submarine operating independently.

Reclassification occurs upon reduction of the number of remaining submarines within a "wolfpack" to a value less than the specified parameter SUBBKPT. (NOTE: each element of the matrix SUBQTY is considered to define at most one "wolfpack".) The parameter SUBBKPT should be defined equal to zero for any type of submarine operating independently. The parameter SUBRETYPE defines the type of "wolfpack" submarines reclassified as each type of submarine ("wolfpack" or submarines operating independently). (NOTE: if none, the parameter SUBRETYPE should be

defined equal to the same type for submarines always operating independently; and for each initial "wolfpack" type, the equivalent type of submarine operating independently.)

Sufficient types of threat submarines must be defined to allow for decrements of "wolfpacks" (that is, if effectiveness is to diminish). The tracks of all such associated submarine types must be identical (due to the data structure employed); as a "wolfpack" suffers attrition, the submarines continue along the same track but with decreasing effectiveness. The operational tasking of these submarines may be altered, however.

Each submarine patrol track is defined by the parameter SUBAREA; for each day of the deployment, the geographic position of the submarine is specified by an ocean area. (Each ocean area is labeled by an integer of value from one to AREAQTY, the number of ocean areas.) Any days on which the threat submarine remains at base for resupply are to be included in the defined track; each base may be labeled by any integer value exceeding AREAQTY, or zero. If parametric attrition of these submarines while at base is desired, the appropriate base must be nominally defined to be an ocean area.

The submarine patrol cycle is further defined by three input values; SUBON, the first day of arrival on station for the deployment; SUBOFF, the day of departure off station for the deployment; and SUBEND, the number of days for each deployment.

Sailings of submarines are specified by the deployment schedule input as SUBSKED. If desired, submarines may be deployed on D-Day; these submarines must be defined in the parameter SUBQTY. Any submarine deployed

on D-Day will begin a new patrol cycle upon completion of resupply and need not be included in the deployment schedule.

Upon completion of the on station patrol (endurance limit) or depletion of on board weapons (whichever occurs first), a submarine departs the patrol area for resupply. A specified percentage of each type of submarine proceeds to out of area resupply; all other submarines must return to the appropriate base. An additional track for each type of submarine must be defined for out of area resupply to include all days from departure off station to the return to on station patrol (defined by SUBOARAREA).

Parameter values reflecting submarine effectiveness (SUBPDET_ _ _, SUBPKILL _ _ _, SUBPENG _ _ _) are to be defined for one threat submarine interacting with one opposing platform or protected force within the daily time step. The exception to this definition is for the parameter SUBPKILLIND for "wolfpack" submarines; the probability of kill is here to be specified for one "wolfpack" attacking an independent ship. If "wolfpacks" disperse to attack independent shipping, the probability of kill is then specified for a threat submarine.

Threat submarines may be defined as maintaining any of two types of weapons on board; conventional torpedoes or missiles labeled SLCM. Initial inventories of each are to be specified by the parameters SUBTORPLOAD and SUBSLCMLOAD.

Parametric attrition to threat submarines from other warfare areas is defined by the parameter OTHERPKSUB. Inventories of any weapons remaining on board are reduced proportionate to element attrition.

B. ATTACK SUBMARINE

Attack submarines are defined to be all friendly submarines, regardless of fleet classification, tasked to counter the threat submarine force. Attack submarines may be allocated to area or barrier search, including coordinated barrier stations, or to direct support of a convoy, underway replenishment group, or battle group. These submarines may be deployed to any ocean area.

Assignment to area or barrier search is defined by the parameter SSNQTY; assignment to direct support is defined by the appropriate parameter (CONSCREEN, URGSCREEN, BGSCREEN).

Any number of different types of attack submarines may be allocated to area or barrier search operations. Submarines assigned to direct support are assumed to be homogeneous within the defined screen specific to each type of protected force; parameter values must reflect the type of submarine assigned.

Attack submarine track definition (parameter SSNAREA) and type specification is in accordance with the corresponding description for threat submarines. Provisions exist for employment of attack submarines within "wolfpacks" or coordinated barrier stations.

The function ATTACKSUBMARINE computes the results of interaction between threat submarines and attack submarines assigned to area or barrier search. Interaction between threat submarines and attack submarines assigned to direct support is explained within the applicable protected force description.

Attack submarines prosecute any threat submarines within the ocean area assigned as defined by the parameters SSNPDETSUB, the probability of detection, and SSNPKILLSUB, the probability of kill (given a detection). False contacts must be accounted for in the parameter SSNPDETSUB. Threat submarines are prosecuted as if operating independently regardless of any threat "wolfpack" operations. Threat submarines may counterattack, as defined by the parameter SUBPKILLSSN, but otherwise avoid any contact with the attack submarine force. These parameters are to be defined for one attack submarine interacting with one threat submarine within the daily time step. The only exception to this rule is for SSNPKILLSUB for coordinated barrier stations; the probability of kill is then defined for the attack "wolfpack".

Attack submarines may be defined as maintaining any of three types of weapons on board; conventional torpedoes, and two types of missiles labeled TASM and TLAM. Initial inventories of each are to be specified by the parameters SSNTORPLOAD, SSNTASMLOAD, and SSNTLAMLOAD.

Attack submarines utilize torpedoes only to attack threat submarines (as threat submarines utilize torpedoes only to counterattack). Inventories of torpedoes only are then reduced for attacks, while all weapons are reduced proportionate to element attrition.

Computations within the function ATTACKSUBMARINE proceed in accordance with the description of II.A.

Attrition to threat submarines is determined and allocated to each type of attack submarine. Any operative constraint (as defined by SSNSUBENGLMT) and the resultant adjustment of threat submarine attrition is applied. Attack submarine inventories of torpedoes are reduced for attacks in accordance with SSNTORPPERSUB.

Threat submarines counterattack as defined by the parameter SUBPKILLSSN. Attrition to the attack submarines is then determined and allocated to each type of threat submarine. Threat submarine inventories of torpedoes are reduced for counterattacks in accordance with SUBTORPPERSSN.

Force levels of both the attack and the threat submarines are then reduced for this attrition. Remaining inventories of weapons on board all submarines are then reduced proportionate to the element attrition.

Parametric attrition to attack submarines from other warfare areas is defined by the parameter OTHERPKSSN. Remaining inventories of weapons are reduced proportionate to this attrition.

C. MINES

Minefields may be placed within any ocean area to counter the threat submarine force. A minefield may be comprised of any number of different types of mines, and becomes operative (or is deployed) in accordance with the programmed schedule input as MINESKED. Each ocean area may contain at most one minefield.

Each minefield specific to an ocean area is defined by the parameter MINEQTY; an initial number of each different type of mine is specified. All mines within a minefield become operative simultaneously on the appropriate day scheduled.

Parameters reflecting mine effectiveness (MINEPDET, MINEPKILL) are to be defined for the probability of detection, and then kill, of a transiting threat submarine by a mine. (NOTE: parameters are defined for a mine, not a minefield.) Current effectiveness of a minefield is computed as a function of the number of mines present within the minefield.

Probability of detection, MINEPDET, is defined as: the probability of detection, recognition, and detonation or attack. Probability of kill given detection, MINEPKILL, is then defined only as the probability of a submarine kill given mine detonation or attack. The number of mines expected to detonate to achieve a submarine kill is therefore the reciprocal of the MINEPKILL value (assuming a geometric distribution; see II.A.).

The function MINES computes the results of interaction between the threat submarine force and any minefields. Computations proceed in accordance with II.A.

Attrition to the threat submarines transiting the minefield is determined and allocated to each type of mine. Submarine force levels are then reduced for this attrition; submarine inventories of all weapons are reduced proportionate to these losses.

The number of mines within the minefield is reduced for attacks to reflect the diminished effectiveness of the minefield. Any other decay or sterilization of the minefield is to be defined by the parameter OTHERPKMINE. To effect sterilization of the minefield, this parameter or MINEQTY may be altered interactively.

D. MARITIME PATROL AIRCRAFT

Maritime patrol aircraft are defined as all land-based ASW patrol aircraft tasked to counter the threat submarine force. Aircraft may be allocated to area or barrier search within any ocean area, or to direct support of a convoy, underway replenishment group, or battle group. Assignment to area or barrier search is defined implicitly by VPQTY; the number of aircraft allocated to each ocean area is to be

specified as the number of patrol stations maintained. Computations to determine the number of stations maintained as a function of the aircraft allocated, transit requirements, and availability are external to the model.

Assignment of aircraft to direct support is defined by the appropriate parameter: CONSCREEN, URGSCREEN, or BGSCREEN. Aircraft may be allocated to each screen as the number of patrol stations maintained or patrol aircraft assigned; the user's choice must be consistant with the values specified for firepower scores, and expected losses.

Any number of different types of patrol aircraft may be allocated to area or barrier search operations. Aircraft assigned to direct support are assumed to be homogeneous within the defined screen specific to each type of protected force; defined parameter values must reflect the type of aircraft assigned.

The function PATROLAIRCRAFT computes the results of interaction between threat submarines and maritime patrol aircraft assigned to area or barrier search operations. Interaction between threat submarines and aircraft allocated to direct support is explained within the applicable protected force description.

Patrol aircraft will prosecute, within the area assigned, any available submarine probability areas or flaming datums resulting from attacks on independent shipping in lieu of area or barrier search.

Undersea surveillance systems provide detection capabilities within each ocean area as defined by the parameter SOSUSPDETSUB. The surveillance system within an area may be programmed to become inoperative at a specified time, in accordance with SOBSUSSKED, to reflect its operational loss.

Flaming datums result from threat submarine attacks on independent shipping; these datums are only prosecuted for one day, and only by maritime patrol aircraft within the same ocean area.

Detections by undersea surveillance systems and flaming datums are assumed to be independent but not mutually exclusive. The combined number of SPAs and flaming datums to be prosecuted is thus computed. No false or duplicate datums are assumed or prosecuted.

If SPAs or flaming datums are prosecuted, redetection by maritime patrol aircraft is defined by the parameter VPPDETDAT, the probability of detecting the threat submarine given a probability area or datum. If no such probability areas are available, MPA stations employ area or barrier search tactics as applicable for the ocean area and implicitly defined by the parameter VPPDETSUB, the probability of detecting a threat submarine. Given detection, regardless if obtained by prosecution of a probability area or by area or barrier search, the probability of kill (given an attack) is to be specified by the parameter VPPKILLSUB. These parameters (VPPDETDAT, VPPDETSUB, and VPPKILLSUB) are to be defined for one maritime patrol aircraft station interacting with one threat submarine within the daily time step.

Threat submarines are prosecuted as if operating independently regardless of any threat "wolfpack" operations. Threat submarines may counterattack as defined by the parameter SUBKILLVP (for example, with missiles; however, inventory of these weapons is not maintained within the model), but otherwise seek to avoid any contact with the patrol aircraft.

Computations within the function PATROLAIRCRAFT proceed in general with the description of II.A.

Attrition to the threat submarines is determined and allocated to each type of patrol aircraft. Any operative constraint (that is, VPSUBENGLMT) and the resultant adjustment of the threat submarine attrition is applied.

Threat submarines counterattack as defined by SUBPKILLVP. Attrition to the patrol aircraft stations is determined and allocated to each type of threat submarine.

Force levels of both the maritime patrol aircraft stations and the threat submarines are then reduced for attrition. Threat submarine inventories of weapons are reduced proportionate to element attrition.

Parametric attrition to maritime patrol aircraft from other warfare areas is defined by the parameter OTHERPKVP. Any other decay of MPA force levels may also be specified by OTHERPKVP. Exponentional decay of force levels is often assumed, but often for ease of computations only.

Threat submarines proceeding to and from out of area resupply may only be prosecuted by maritime patrol aircraft. To avoid duplicate utilization of MPA forces (the function does not permit the prosecution of both submarines on patrol and submarines proceeding to OOA resupply within the same ocean area on a given day), the specified track for out of area resupply should exclude any threat submarine patrol areas. Prosecution of these submarines is in accordance with the preceding description and computed within the same function PATROLAIRCRAFT. Previously defined parameters reflecting MPA effectiveness must be defined for these ocean areas.

E. INDEPENDENT SHIPPING

Independent shipping is defined as any merchant or military shipping transiting independently without benefit of protection by naval forces. Any number of different types of shipping may transit through any ocean areas. These different types of shipping must be defined to reflect differences in cargo, SLOC utilization, or other considerations.

Each track, specific to each type of shipping, is defined by the parameter INDAREA; for each day of the transit, the geographic position of a ship is specified by an ocean area.

The schedule of independent ship sailings for the campaign is to be input as the parameter INDSKED. If desired, independent ships may be enroute on D-Day; these ships must be defined in the parameter INDQTY.

Transits of each type of shipping may be defined for either delivery only, or to include the return track. Upon completion of the defined track, no further accounting of an independent ship exists within the model. Each sailing of any independent ship must be explicitly scheduled by INDSKED.

Caution must be exercised with regard to the independent shipping schedule; later departures may be dependent upon the survival of earlier sailings. Arrivals of independent ships, upon completion of the appropriate track, are tallied for each type of ship for each day of the campaign. These arrivals should be monitored, or reviewed, to determine the validity of available merchant assets throughout the campaign.

Threat submarines, with the appropriate tasking as defined by the parameter SUBTASKIND, attack independent ships in accordance with the specified probability of detection, SUBPDETIND, and probability of kill

given detection, SUBPKILLIND. Submarines utilize conventional torpedoes only for these attacks; the parameter SUBTORPPERIND defines the number of torpedoes expended for each attack.

Independent ships may counterattack as defined by the parameter INDPKILLSUB, but otherwise seek to avoid any contact with the threat submarines.

The parameters SUBPDETIND, SUBPKILLIND, and INDPKILLSUB are to be defined for one threat submarine interacting with one independent ship within the daily time step. For a threat "wolfpack", SUBPKILLIND is to be defined for the "wolfpack" attacking an independent ship.

The function INDEPSHIP computes the results of interaction between threat submarines and independent shipping. Computations within the function proceed in accordance with the description of II.A.

Attrition to independent shipping is determined and allocated to each type of threat submarine. Any operative constraint (that is, SUBINDENGLMT) and the resultant adjustment of independent ship attrition is applied. Threat submarine inventories of torpedoes are reduced for attacks in accordance with SUBTORPPERIND.

Independent ships counterattack as defined by INDPKILLSUB; attrition to the threat submarines is determined and allocated to each type of independent shipping.

Force levels of both the threat submarines and the independent ships are reduced for attrition. Threat submarine inventories are further reduced proportionate to element attrition.

Parametric attrition to independent shipping from other warfare areas is specified by the parameter OTHERPKIND. This attrition, for example, may result from attacks on shipping by threat naval surface forces.

F. CONVOY

A convoy is defined to be any merchant shipping transiting with the protection of naval forces to counter threat naval forces. Any number of different types of convoys may be defined and transit through any ocean areas. These different types must be created to reflect differences in cargo, SLOC utilization, screen composition, speed of advance, and other considerations. If desired, each convoy may be created as a specific type.

Each convoy track, specific to each type of convoy, is to be defined by the parameter CONAREA; for each day of the transit, the geographic position of a convoy is specified by an ocean area.

The schedule of convoy departures for the campaign is to be input as the parameter CONSKED; the number of merchant ships sailing within each convoy is to be specified. Each element of the matrix CONSKED may define at most one convoy.

Upon departure, each convoy is provided with a screen comprised of a specified number of elements of at most three different platforms. These platforms are nominally labeled as maritime patrol aircraft, attack submarines, and surface escorts. Any three platforms desired may be employed; computations are identical within the function CONVOY for each platform. Each convoy of the same type is provided with an identical screen as defined by CONSCREEN, regardless of the number of merchant ships sailing within the convoy. Elements assigned to each convoy accompany the force for the entire transit; (this does not imply that the screen does not suffer attrition).

If desired, convoys may be deployed on D-Day; these forces must be defined by the parameters CONMERQTY,CONVPQTY, CONSSNQTY, and CONESCQTY

(screen composition must by consistant with the parameter CONSCREEN). The corresponding elements of these matrices may define at most one convoy.

Transits of each type of convoy may be defined for either delivery only or to include the return track. Upon completion of the defined track, no further accounting of a convoy exists within the model. Each sailing of any convoy must be scheduled by CONSKED.

Caution must be exercised with regard to the convoy schedule; later departures may be dependent upon the survival of earlier sailings. Arrivals of merchant ships and screening elements, upon completion of the appropriate track are tallied for each type of convoy for each day of the campaign. These arrivals should be monitored, or reviewed, to determine the validity of available assets throughout the campaign.

A firepower index is used to aggregate the ASW effectiveness of each screening element and, if appropriate, the merchant ships within each convoy. Each element is weighted by a firepower score to reflect the relative contribution of each platform to the total convoy ASW effectiveness. These firepower scores are defined for the original screen (as specified by CONSCREEN) and merchant ships within a convoy interacting with a threat submarine.

Threat submarines, with the appropriate tasking as defined by the parameter SUBTASKCON, engage convoys in accordance with the specified probability of engagement, SUBPENGCON. Threat submarines may utilize either torpedoes or missiles to attack convoys; the number of weapons expended for each attack on a convoy is specified within the parameter CONEXPLOSS. Convoy forces will counterattack, but otherwise avoid any contact with the threat submarines.

Attrition is defined by the parameter CONEXPLOSS for an engagement between a convoy (of original force levels) and a threat submarine, or "wolfpack". Expected losses are specified for each type of platform within the screen, the merchant ships, and the threat submarine, or "wolfpack".

The function CONVOY computes the results of interaction between the convoy and threat submarine forces. Computations proceed as described in II.B.

The number of convoys engaged by threat submarines is determined and allocated to each type of threat submarine. Any operative constraint (that is, SUBCONENGLMT), and resultant adjustment of engagements is applied. Engagements by each type of threat submarine are then allocated to each convoy.

The current ASW firepower index of each convoy is determined and expressed relative to a reference index (that is, percentage of REFCONFPINDEX). Expected losses to each convoy attacked, and to each threat submarine counterattacked, are determined and adjusted for the current ASW effectiveness of the convoy for each engagement. Torpedo and missile expenditure for attacks by the threat submarine is similarly computed.

Inventories of remaining weapons on board threat submarines are then further reduced proportionate to element attrition.

Parametric attrition to elements within the convoy from other warfare is to be specified by the parameters OTHERPKCONMER, OTHERPKCONVP, OTHERPKCONSSN, and OTHERPKCONESC. For example, attrition to these forces resulting from a threat aircraft strike may be effected by interactively varying these parameters for the day of the strike.

G. UNDERWAY REPLENISHMENT GROUP

An underway replenishment group is defined to be any naval auxiliary ships deployed with the protection of naval forces. Any number of different types of underway replenishment groups may be defined and deployed within any ocean areas. These different types must be created to reflect differences in fleet classifications, operation areas, SLOC utilization, screen composition, and other considerations. If desired, each underway replenishment group may be created as a specific type.

Each underway replenishment group track, specific to each type of underway replenishment group, is to be defined by the parameter URGAREA; for each day of the deployment, the geographic position of an underway replenishment group is specified by an ocean area.

The schedule of underway replenishment group departures for the campaign is to be input as the parameter URGSKED; the number of auxiliary ships sailing within each underway replenishment group is to be specified. Each element of the matrix URGSKED may define at most one underway replenishment group.

Upon a scheduled departure, each underway replenishment group is provided with a screen comprised of a specified number of elements of at most three different platforms. These platforms are nominally labeled as maritime patrol aircraft, attack submarines, and surface escorts. Any three platforms desired may be employed; computations are identical within the function UNREPGROUP for each platform. Each underway replenishment group of the same type is provided with an identical screen as defined by URGSCREEN, regardless of the number of auxiliary ships sailing within the underway replenishment group. Elements assigned

to each underway replenishment group accompany the force for the entire deployment; (this does not imply that the screen does not suffer attrition).

If desired, underway replenishment groups may be deployed on D-Day; these forces must be defined by the parameters URGAUXQTY, URGVPQTY, URGSSNQTY, and URGESCQTY (screen composition must be consistant with the parameter URGSCREEN). The corresponding elements of these matrices may define at most one underway replenishment group.

Transits of each type of underway replenishment group must be defined for an entire deployment from departure to the return arrival and any days required for resupply or turn-around. An underway replenishment group will begin a new cycle upon completion of turn-around; these departures need not be included in the deployment schedule URGSKED. However, the number of elements of each type then sailing within each underway replenishment group remains the same as those that completed the last cycle. (That is, a new screen is not provided as defined by URGSCREEN.)

A firepower index is used to aggregate the ASW effectiveness of each screening element and, if appropriate, the auxiliary ships within each underway replenishment group. Each element is weighted by a firepower score to reflect the relative contribution of each platform to the total underway replenishment group ASW effectiveness. These firepower scores are defined for the original screen (as specified by URGSCREEN) and auxiliary ships within an underway replenishment group interacting with a threat submarine.

Threat submarines, with the appropriate tasking as defined by the parameter SUBTASKURG, engage underway replenishment groups in accordance with the specified probability of engagement, SUBPENGURG. Threat submarines may utilize either torpedoes or missiles to attack underway replenishment groups; the number of weapons expended for each attack on an underway replenishment group is specified within the parameter URGEXPLOSS. Underway replenishment group forces will counterattack, but otherwise avoid any contact with the threat submarines.

Attrition is defined by the parameter URGEXPLOSS for an engagement between an underway replenishment group (of original force levels) and a threat submarine, or "wolfpack". Expected losses are specified for each type of platform within the screen, the auxiliary ships, and the threat submarine, or "wolfpack".

The function UNREPGROUP computes the results of interaction between the underway replenishment group and threat submarine forces. Computations proceed as described in II.B.

The number of underway replenishment groups engaged by threat submarines is determined and allocated to each type of threat submarine. Any operative constraint (that is, SUBURGENGLMT), and resultant adjustment of engagements is applied. Engagements by each type of threat submarine are then allocated to each underway replenishment group.

The current ASW firepower index of each underway replenishment group is determined and expressed relative to a reference index (that is, percentage of REFURGFPINDEX). Expected losses to each underway replenishment group attacked, and to each threat submarine counterattacked, are determined and adjusted for the current ASW effectiveness

of the underway replenishment group for each engagement. Torpedo and missile expenditure for attacks by the threat submarine is similarly computed.

Inventories of remaining weapons on board threat submarines are then further reduced proportionate to element attrition.

Parametric attrition to elements within the underway replenishment group from other warfare is to be specified by the parameters OTHERPKURGAUX, OTHERPKURGVP, OTHERPKURGSSN, and OTHERPKURGESC. For example, attrition to these forces resulting from a threat aircraft strike may be effected by interactively varying these parameters for the day of the strike.

H. BATTLE GROUP

A battle group is defined to be any aircraft carriers deployed with the protection of naval forces. Any number of different types of battle groups may be defined and deployed within any ocean areas. These different types must be created to reflect differences in fleet classifications, operation areas, SLOC protection, screen composition, and other considerations. If desired, each battle group may be created as a specific type.

Each battle group track, specific to each type of battle group, is to be defined by the parameter BGAREA; for each day of the deployment, the geographic position of a battle group is specified by an ocean area.

The schedule of battle group departures for the campaign is to be input as the parameter BGSKED; the number of aircraft carriers sailing within each battle group is to be specified. Each element of the matrix BGSKED may define at most one battle group.

Upon a scheduled departure, each battle group is provided with a screen comprised of a specified number of elements of at most three different platforms. These platforms are nominally labeled as maritime patrol aircraft, attack submarines, and surface escorts. Any three platforms desired may be employed; computations are identical within the function BATTLEGROUP for each platform. Each battle group of the same type is provided with an identical screen as defined by BGSCREEN, regardless of the number of aircraft carriers sailing within the battle group. Elements assigned to each battle group accompany the force for the entire deployment; (this does not imply that the screen does not suffer attrition).

If desired, battle groups may be deployed on D-Day; these forces must be defined by the parameters BGCVQTY, BGVPQTY, BGSSNQTY, and BGESCQTY (screen composition must be consistant with the parameter BGSCREEN). The corresponding elements of these matrices may define at most one battle group.

Transits of each type of battle group must be defined for an entire deployment from departure to the return arrival and any days required for resupply or turn-around. A battle group will begin a new cycle upon completion of turn-around; these departures need not be included in the deployment schedule BGSKED. However, the number of elements of each type then sailing within each battle group remains the same as those that completed the last cycle. (That is, a new screen is not provided as defined by BGSCREEN.)

A firepower index is used to aggregate the ASW effectiveness of each screening element and the aircraft carriers within each battle group.

Each element is weighted by a firepower score to reflect the relative contribution of each platform to the total battle group ASW effectiveness. These firepower scores are defined for the original screen (as specified by BGSCREEN) and aircraft carriers within a battle group interacting with a threat submarine.

Threat submarines, with the appropriate tasking as defined by the parameter SUBTASKBG, engage battle groups in accordance with the specified probability of engagement, SUBPENGBG. Threat submarines may utilize either torpedoes or missiles to attack battle groups; the number of weapons expended for each attack on a battle group is specified within the parameter BGEXPLOSS. Battle group forces will counterattack, but otherwise avoid any contact with the threat submarines.

Attrition is defined by the parameter BGEXPLOSS for an engagement between a battle group (of original force levels) and a threat submarine, or "wolfpack". Expected losses are specified for each type of platform within the screen, the aircraft carriers, and the threat submarine, or "wolfpack".

The function BATTLEGROUP computes the results of interaction between the battle group and threat submarine forces. Computations proceed as described in II.B.

The number of battle groups engaged by threat submarines is determined and allocated to each type of threat submarine. Any operative constraint (that is, SUBBGENGLMT), and resultant adjustment of engagements is applied. Engagements by each type of threat submarine are then allocated to each battle group.

The current ASW firepower index of each battle group is determined and expressed relative to a reference index (that is, percentage of REFBGFPINDEX). Expected losses to each battle group attacked, and to each threat submarine counterattacked, are determined and adjusted for the current ASW effectiveness of the battle group for each assessment. Torpedo and missile expenditure for attacks by the threat submarine is similarly computed.

Inventories of remaining weapons on board threat submarines are then further reduced proportionate to element attrition.

Parametric attrition to elements within the battle group from other warfare is to be specified by the parameters OTHERPKBGCV, OTHERPKBGVP, OTHERPKBGSSN, and OTHERPKBGESC. For example, attrition to these forces resulting from a threat aircraft strike may be effected by interactively varying these parameters for the day of the strike.

The model has been programmed in the APL computer language to permit the matrix applications which provide the required flexibility for the campaign analysis. The APL translation has been written for efficiency as well as clarity; (though efficiency has been sacrificed to some extent to promote clarity). Parameter names have been chosen to literally equate with the corresponding definitions.

The CPU time required to execute the model will vary directly with the number of ocean areas defined, and the duration of the campaign; each APL function which determines the outcome of pairwise interactions is executed for each ocean area for each day of the campaign. The APL workspace size required will depend primarily upon the number of ocean

areas defined, the duration of the campaign, and the number of different types and cycle durations specified for each platform.

The APL translation of each model function is enclosed; documentation within each function is minimal to avoid an excessive workspace size requirement. (58 records are required for an APL workspace to contain all model functions.) The function INITIALIZE is provided to facilitate the creation of a database for the required input parameters. The user interactively defines key input parameters; the function then creates appropriately sized vectors, matrices, or three-dimensional arrays for all input parameters. Output parameters are defined in Appendix B. The user may easily define any desired output sequence and labeling.

Attrition statistics are collected throughout the model to record the results of the numerous interactions between threat and friendly forces. Attrition to each type of platform, including platforms within a protected force, is tallied for each day of the campaign, and for each ocean area. Attrition to each type of threat submarine is also tallied by the platform, or protected force, inflicting the losses for each day of the campaign, and for each ocean area.

Cumulative attrition to each type of friendly platform is tallied by the type of threat sumbarine inflicting the losses. Similarly, cumulative attrition to each type of threat submarine is tallied by the type of friendly platform, or protected force, inflicting the losses.

Parametric attrition for other warfare areas to any platform is only reflected in the appropriate statistic (the appropriate parameter ___ ATTRIT) tallying attrition for each platform type for each day of the campaign.

IV. CONCLUSION

Extensive analysis and modeling has been previously employed to enhance insight into the ASW campaign. This attempt to model the numerous interactions between the threat submarine force and friendly naval forces and merchant, and military, shipping provides improved flexibility and options to examine a myriad of scenarios. The principal feature unique to this campaign model allows for attrition to both threat and friendly forces.

The use of a firepower approach is infrequent within naval campaign analyses; however, firepower indices provide a means to aggregate the effectiveness of heterogeneous forces, as opposed to an assumption of homogeneity. The model allows for saturation, in the sense that limited attrition to a friendly force does not necessarily degrade the performance of the friendly force proportionate to the losses. This effect is often recognized to occur given ASW defense in depth.

Any campaign model must be used with caution; the results obtained are valid only to the extent that the assumptions of the model, and the tactics and strategy implied, hold to be true. The assumption that force levels are "not small" and "not near parity" must hold if this deterministic model is to yield viable results [TAYLOR, J.G. 1980].

The campaign model should be used as an illustrative, and not necessarily predictive, tool by the naval decision-maker. Through extensive analysis of varied scenarios, critical areas of operations may be identified, the feasibility of strategies may be determined, and cautiously, the adequacy of force levels may be evaluated.

The campaign model does not examine the dynamics of tactical interaction, however. The model is simply an aggregated "bookkeeping" approach to an ASW campaign. Any microscopic look at tactical interaction must be examined within an appropriate engagement model. The output of these highly-detailed models then may be utilized to define input parameters to the campaign model.

The assumptions required to employ the model have been described in the previous chapters; several of these premises need to be emphasized. For each pairwise interaction, one platform only is assumed to initiate an engagement. Independent shipping will most likely seek to avoid any contact with the threat submarines; however, naval forces in direct support of a battle group might indeed close an unsuspecting threat submarine. If this opportunity is relatively infrequent, then the assumption may remain valid.

Though the model determines attrition to merchant shipping, the validity of adequate ships to meet the campaign shipping schedule requires constant review. The number of merchant ships lost will be overestimated if ships no longer exist to maintain the programmed schedule.

Throughout the campaign adequate logistics are assumed. However, the survival of the battle groups may greatly depend upon the survival of the underway replenishment groups. Likewise, the ability of maritime patrol aircraft to perform the assigned mission may depend upon a sufficient supply of spare parts, sonobuoys, and torpedoes. The complex logistics for a naval campaign should be evaluated to determine the degree of degradation to operational performance that may result.

Validation of any campaign model is a most difficult task; historic data of only limited interest is available to provide a "benchmark". Major studies, such as SEAWAR 85, may provide a basis for comparison. However, these studies have also utilized mathematical models to determine attrition, and often only to the threat force.

Acceptability of this campaign model is currently under study by OP-96, the Office of the Chief of Naval Operations. Complete validation, however, will not be easily accomplished; attrition to threat submarines only may be directly compared with other study results. Subjective analysis must then be applied to evaluate the attrition to friendly forces.

APPENDIX A: LIST OF INPUT PARAMETERS

PARAMETER NAME

Shape or dimension of parameter (array = three-dimensional array); dimension labels (for matrix: rows by columns; for three-dimensional array: pages by rows by columns); parameter definition.

AREAQTY

Scalar; number of ocean areas.

BGAREA

Matrix; battle group type by day of cycle; battle group track.

BGCVQTY

Matrix; battle group type by day of cycle; number of aircraft carriers.

BGEND

Vector; by battle group type; last day of battle group cycle.

BGESCQTY

Matrix; battle group type by day of cycle; number of surface escorts.

BGEXP

Matrix; threat submarine type X battle group type by 7 (VP; SSN; ESC; CV; TORP; SLCM; SUB); shape parameter per expected loss curve.

BGEXPLOSS

Matrix; threat submarine type X battle group type by 7 (VP; SSN; ESC; CV; TORP; SLCM; SUB); expected loss per engagement.

BGFPSCORE

Matrix; battle group type by 4 (VP; SSN; ESC; CV); firepower score per unit.

BGSCREEN

Matrix; battle group type by 3 (VP; SSN; ESC); number of units assigned per battlegroup.

BGSKED

Matrix; battle group type by day of campaign; number of aircraft carriers sailing.

BGSSNQTY

Matrix; battle group type by day of cycle; number of attack submarines.

BGVPQTY

Matrix; battle group type by day of cycle; number of maritime patrol aircraft stations.

CONAREA

Matrix; convoy type by day of cycle; convoy track.

CONEND

Vector; by convoy type; last day of convoy cycle.

CONESCQTY

Matrix; convoy type by day of cycle; number of surface escorts.

CONEXP

Matrix; threat submarine type X convoy type by 7 (VP; SSN; ESC; MER; TORP; SLCM; SUB); shape parameter per expected loss curve.

CONEXPLOSS

Matrix; threat submarine type X convoy type by 7 (VP; SSN; ESC; MER; TORP; SLCM; SUB); expected loss per engagement.

CONFPSCORE

Matrix; convoy type by 4 (VP; SSN; ESC; MER); firepower score per unit.

CONMERQTY

Matrix; convoy type by day of cycle; number of surface escorts.

CONSCREEN

Matrix; convoy type by 3 (VP; SSN; ESC); number of units assigned per convoy.

CONSKED

Matrix; convoy type by day of campaign; number of merchant ships sailing.

CONSSNQTY

Matrix; convoy type by day of cycle; number of attack submarines.

CONVPQTY

Matrix; convoy type by day of cycle; number of maritime patrol aircraft stations.

DAYOFF

Scalar; 1: printout of day of campaign as execution of same begins; 0: printout suppressed.

DURATION

Scalar; number of days in campaign.

INDAREA

Matrix; independent shipping type by day of cycle; independent ship track.

INDEND

Vector; by independent shipping type; last day of independent ship cycle.

INDPKILLSUB

Array; ocean area by threat submarine type by independent shipping type; probability of kill given attack, independent ship counterattack of threat submarine.

INDQTY

Matrix; independent shipping type by day of cycle; number of independent ships.

INDSKED

Matrix; independent shipping type by day of campaign; number of independent ships sailing.

MINEPDET

Array; ocean area by threat submarine type by mine type; probability of detection given opportunity, mine detection of threat submarine.

MINEPKILL

Array; ocean area by threat sumbarine type by mine type; probability of kill given detection, mine attack of threat submarine.

MINEQTY

Matrix; mine type by ocean area; number of mines.

MINESKED

Vector; by ocean area; first day of campaign that minefield is effective.

OTHERPKBGCV

Matrix; battle group type by ocean area; percentage attrition to aircraft carriers due other warfare.

OTHERPKBGESC

Matrix; battle group type by ocean area; percentage attrition to surface escorts due other warfare.

OTHERPKBGSSN

Matrix; battle group type by ocean area; percentage attrition to attack submarines due other warfare.

OTHERPKBGVP

Matrix; battle group type by ocean area; percentage attrition to maritime patrol aircraft due other warfare.

OTHERPKCONESC

Matrix; convoy type by ocean area; percentage attrition to surface escorts due other warfare.

OTHERPKCONMER

Matrix; convoy type by ocean area; percentage attrition to merchant ships due other warfare.

OTHERPKCONSSN

Matrix; convoy type by ocean area; percentage attrition to attack submarines due other warfare.

OTHERPKCONVP

Matrix; convoy type by ocean area; percentage attrition to maritime patrol aircraft due other warfare.

OTHERPKIND

Matrix; independent shipping type by ocean area; percentage attrition to independent ships due other warfare.

OTHERPKMINE

Matrix; mine type by ocean area; percentage attrition to mines due other warfare.

OTHERPKSSN

Matrix; attack submarine type by ocean area; percentage attrition to attack submarines due other warfare.

OTHERPKURGAUX

Matrix; underway replenishment group type by ocean area; percentage attrition to auxiliary ships due other warfare.

OTHERPKURGESC

Matrix; underway replenishment group type by ocean area; percentage attrition to surface escorts due other warfare.

OTHERPKURGSSN

Matrix; underway replenishment group type by ocean area; percentage attrition to attack submarines due other warfare.

OTHERPKURGVP

Matrix; underway replenishment group type by ocean area; percentage attrition to maritime patrol aircraft due other warfare.

OTHERPKVP

Matrix; maritime patrol aircraft type by ocean area; percentage attrition to maritime patrol aircraft due other warfare.

PAUSE

Scalar; next day of campaign that execution of model is to be temporarily halted.

REFBGFPINDEX

Vector; by battle group type; reference, or base case, battle group firepower index.

REFCONFPINDEX

Vector; by convoy type; reference, or base case, convoy firepower index.

REFURGFPINDEX

Vector; by underway replenishment group type; reference, or base case, underway replenishment group firepower index.

SOSUSPDETSUB

Matrix; threat submarine type by ocean area; probability of detection given opportunity, undersea surveillance system detection of threat submarine.

SOSUSSKED

Vector; by ocean area; first day of campaign that undersea surveillance system becomes ineffective.

SSNAREA

Matrix; attack submarine type by day of cycle; attack submarine track.

SSNBKPT

Vector; by attack submarine type; minimum number of attack submarines per wolfpack. (If SSNQTY is less than SSNBKPT, attack submarines are retyped.)

SSNEND

Vector; by attack submarine type; last day of attack submarine cycle.

SSNOARAREA

Matrix; attack submarine type by day of out of area resupply cycle; attack submarine track.

SSNOAREND

Vector; by attack submarine type; last day of attack submarine out of area resupply cycle.

SSNOARQTY

Matrix; attack submarine type by day of out of area resupply cycle; number of attack submarines.

SSNOFF

Vector; by attack submarine type; first day of cycle that attack submarine is off station.

SSNON

Vector; by attack submarine type; first day of cycle that attack submarine is on station.

SSNPCTOAR

Vector; by attack submarine type; percentage of attack submarines that transit to out of area resupply, (do not return to base).

SSNPDETSUB

Array; ocean area by threat submarine type by attack submarine type; probability of detection given opportunity, attack submarine detection of threat submarine.

SSNPKILLSUB

Array; ocean area by threat submarine type by attack submarine type; probability of kill given detection, attack submarine attack of threat submarine.

SSNQTY

Matrix; attack submarine type by day of cycle; number of attack submarines.

SSNRETYPE

Vector; by attack submarine type; attack submarine type transferred (retyped) to this attack submarine type. (Wolfpack application.)

SSNSKED

Matrix; attack submarine type by day of campaign; number of attack submarines sailing.

SSNSUBENGLMT

Vector; by attack submarine type; maximum number of threat submarines engaged per attack submarine, (engagement limit).

SSNTASMLOAD

Vector; by attack submarine type; number of TASMs initialized on board each attack submarine.

SSNTLAMLOAD

Vector; by attack submarine type; number of TLAMs initialized on board each attack submarine.

SSNTORPLOAD

Vector; by attack submarine type; number of torpedoes initialized on board each attack submarine.

SSNTORPPERSUB

Matrix; threat submarine type by attack submarine type; number of torpedoes expended per attack, attack submarine attack of threat submarine.

SUBAREA

Matrix; threat submarine type by day of cycle; threat submarine track.

SUBBGENGLMT

Vector; by threat submarine type; maximum number of battle groups engaged per threat submarine, (engagement limit).

SUBBKPT

Vector; by threat submarine type; minimum number of threat submarines per wolfpack. (If SUBQTY is less than SUBBKPT, threat submarines are retyped.)

SUBCONENGLMT

Vector; by threat submarine type, maximum number of convoys engaged per threat submarine, (engagement limit).

SUBEND

Vector by threat submarine type; last day of threat submarine cycle.

SUBINDENGLMT

Vector; by threat submarine type; maximum number of independent ships engaged per threat submarine, (engagement limit).

SUBOARAREA

Matrix; threat submarine type by day of out of area resupply cycle; threat submarine track.

SUBOAREND

Vector; by threat submarine type; last day of threat submarine out of area resupply cycle.

SUBOARQTY

Matrix; threat submarine type by day of out of area resupply cycle; number of threat submarines.

SUBOFF

Vector; by threat submarine type; first day of cycle that threat submarine is off station.

SUBON

Vector; by threat submarine type; first day of cycle that threat submarine is on station.

SUBPCTOAR

Vector; by threat submarine type; percentage of threat submarines that transit to out of area resupply, (do not return to base).

SUBPDETIND

Array; ocean area by threat submarine type by independent shipping type; probability of detection given opportunity, threat submarine detection of independent ship.

SUBPENGBG

Array; ocean area by threat submarine type by battle group type; probability of engagement given opportunity, threat submarine engagement of battle group.

SUBPENGCON

Array; ocean area by threat submarine type by convoy type; probability of engagement given opportunity, threat submarine engagement of convoy.

SUBPENGURG

Array; ocean area by threat submarine type by underway replenishment group type; probability of engagement given opportunity, threat submarine engagement of underway replenishment group.

SUBPKILLIND

Array; ocean area by threat submarine type by independent shipping type; probability of kill given detection, threat submarine attack of independent ship.

SUBPKILLSSN

Array; ocean area by threat submarine type by attack submarine type; probability of kill given attack, threat submarine counterattack of attack submarine.

SUBPKILLVP

Array; ocean area by threat submarine type by maritime patrol aircraft type; probability of kill given attack, threat submarine counterattack of maritime patrol aircraft.

SUBQTY

Matrix; threat submarine type by day of cycle; number of threat submarines.

SUBRETYPE

Vector; by threat submarine type; threat submarine type transferred (retyped) to this threat submarine type. (Wolfpack application.)

SUBSKED

Matrix; threat submarine type by day of campaign; number of threat submarine sailings.

SUBSLCMLOAD

Vector; by threat submarine type; number of SLCMs initialized on board each threat submarine.

SUBTASKBG

Vector; by threat submarine type; percentage threat submarines tasked to engage battle groups.

SUBTASKCON

Vector; by threat submarine type; percentage threat submarines tasked to engage convoys.

SUBTASKIND

Vector; by threat submarine type; percentage threat submarines tasked to engage independent shipping.

SUBTASKURG

Vector; by threat submarine type; percentage threat submarines tasked to engage underway replenishment groups.

SUBTORPLOAD

Vector; by threat submarine type; number of torpedoes initialized on board each threat submarine.

SUBTORPERIND

Matrix; threat submarine type by independent shipping type; number of torpedoes expended per attack, threat submarine attack of independent ship.

SUBTORPERSSN

Matrix; threat submarine type by attack submarine type; number of torpedoes expended per attack, threat submarine counterattack of attack submarine.

SUBURGENGLMT

Vector; by threat submarine type; maximum number of underway replenishment groups engaged per threat submarine; (engagement limit).

URGAREA

Matrix; underway replenishment group type by day of cycle; underway replenishment group track.

URGAUXQTY

Matrix; underway replenishment group type by day of cycle; number of auxiliary ships.

URGEND

Vector; by underway replenishment group type; last day of underway replenishment group cycle.

URGESCQTY

Matrix; underway replenishment group type by day of cycle; number of surface escorts.

URGEXP

Matrix; threat submarine type X underway replenishment group type by 7 (VP; SSN; ESC; AUX; TORP; SLCM; SUB); shape parameter per expected loss curve.

URGEXPLOSS

Matrix; threat submarine type X underway replenishment group type by 7 (VP; SSN; ESC; AUX; TORP; SLCM; SUB); expected loss per engagement.

URGFPSCORE

Matrix; underway replenishment group type by 4 (VP; SSN; ESC; AUX); firepower score per unit.

URGSCREEN

Matrix; underway replenishment group type by 3 (VP; SSN; ESC); number of units assigned per underway replenishment group.

URGSKED

Matrix; underway replenishment group type by day of campaign; number of auxiliary ships sailing.

URGSSNQTY

Matrix; underway replenishment group type by day of cycle; number of attack submarines.

URPVPQTY

Matrix; underway replenishment group type by day of cycle; number of maritime patrol aircraft stations.

VPPDETDAT

Array; ocean area by threat submarine type by maritime patrol aircraft type; probability of detection given datum, maritime patrol aircraft redetection of threat submarine.

VPPDETSUB

Array; ocean area by threat submarine type by maritime patrol aircraft type; probability of detection given opportunity, maritime patrol aircraft detection of threat submarine.

VPPKILLSUB

Array; ocean area by threat submarine type by maritime patrol aircraft type; probability of kill given detection, maritime patrol aircraft attack of threat submarine.

VPQTY

Matrix; maritime patrol aircraft type by ocean area; number of maritime patrol aircraft stations.

VPSUBENGLMT

Vector; by maritime patrol aircraft type; maximum number of threat submarines engaged per maritime patrol aircraft station, (engagement limit).

ZEROSSNTASM

Vector; by attack submarine type; minimum number of TASMs remaining on board an attack submarine to allow same to remain on station.

ZEROSSNTLAM

Vector; by attack submarine type; minimum number of TLAMs remaining on board an attack submarine to allow same to remain on station.

ZEROSSNTORP

Vector; by attack submarine type; minimum number of torpedoes remaining on board an attack submarine to allow same to remain on station.

ZEROSUBSLCM

Vector; by threat submarine type; minimum number of SLCMs remaining on board a threat submarine to allow same to remain on station.

ZEROSUBTORP

Vector; by threat submarine type; minimum number of torpedoes remaining on board a threat submarine to allow same to remain on station.

Format of EXP/EXPLOSS Matrix

INTERACTION	VP LOSS	SSN LOSS	ESC LOSS	TGT LOSS	TORP EXP	SLCM EXP	SUB LOSS
SUBTYPE1 vs TGTTYPE1							
SUBTYPE1 vs TGTTYPE2							
...							
SUBTYPE1 vs TGTTYPEn							
SUBTYPE2 vs TGTTYPE1				(mn by 7 matrix)			
SUBTYPE2 vs TGTTYPE2							
...							
SUBTYPE2 vs TGTTYPEn							
...							
SUBTYPEm vs TGTTYPE1							
SUBTYPEm vs TGTTYPE2							
...							
SUBTYPEm vs TGTTYPEn							

m types of threat submarines; n types of forces

APPENDIX B: LIST OF OUTPUT PARAMETERS

PARAMETER NAME

Shape or dimension of parameter (array = three-dimensional array); dimension labels (for matrix: rows by columns; for three-dimensional array: passes by rows by columns); parameter definition.

AREABGCVLOSS

Matrix; ocean area by battle group type; attrition to aircraft carriers due threat submarines.

AREABGESCLOSS

Matrix; ocean area by battle group type; attrition to surface escorts within battle groups due threat submarines.

AREABGSSNLOSS

Matrix; ocean area by battle group type; attrition to attack submarines within battle groups due threat submarines.

AREABGSUBLOSS

Matrix; ocean area by threat submarine type; attrition to threat submarines due battle groups.

AREABGVPLOSS

Matrix; ocean area by battle group type; attrition to maritime patrol aircraft within battle groups due threat submarines.

AREACONESCLOSS

Matrix; ocean area by convoy type; attrition to surface escorts within convoys due threat submarines.

AREACONMERLOSS

Matrix; ocean area by convoy type; attrition to merchant ships within convoys due threat submarines.

AREACONSSNLOSS

Matrix; ocean area by convoy type; attrition to attack submarines within convoys due threat submarines.

AREACONSUBLOSS

Matrix; ocean area by threat submarine type; attrition to threat submarines due convoys.

AREACONVPLOSS

Matrix; ocean area by convoy type; attrition to maritime patrol aircraft within convoys due threat submarines.

AREAINDLOSS

Matrix; ocean area by independent shipping type; attrition to independent ships due threat submarines.

AREAINDSUBLOSS

Matrix; ocean area by threat submarine type; attrition to threat submarines due independent shipping.

AREAMINESUBLOSS

Matrix; ocean area by threat submarine type; attrition to threat submarines due mines.

AREASSNLOSS

Matrix; ocean area by attack submarine type; attrition to attack submarines due threat submarines.

AREASSNSUBLOSS

Matrix; ocean area by threat submarine type; attrition to threat submarines due attack submarines.

AREASUBLOSS

Matrix; ocean area by threat submarine type; attrition to threat submarines.

AREAURGAUXLOSS

Matrix; ocean area by underway replenishment group type; attrition to auxiliary ships within underway replenishment groups due threat submarines.

AREAURGESCLOSS

Matrix; ocean area by underway replenishment group type; attrition to surface escorts within underway replenishment groups due threat submarines.

AREAURGSSNLOSS

Matrix; ocean area by underway replenishment group type; attrition to attack submarines within underway replenishment groups due threat submarines.

AREAURGSUBLOSS

Matrix; ocean area by threat submarine type; attrition to threat submarines due underway replenishment groups.

AREAURGVPLOSS

Matrix; ocean area by underway replenishment group type; attrition to maritime patrol aircraft within underway replenishment groups due threat submarines.

AREAVPLOSS

Matrix; ocean area by maritime patrol aircraft type; attrition to maritime patrol aircraft due threat submarines.

AREAVPSUBLOSS

Matrix; ocean area by threat submarine type; attrition to threat submarines due maritime patrol aircraft.

BGCVATTRIT

Matrix; day of campaign by battle group type; attrition to aircraft carriers.

BGESCATTRIT

Matrix; day of campaign by battle group type; attrition to surface escorts within battle groups.

BGSSNATTRIT

Matrix; day of campaign by battle group type; attrition to attack submarines within battle groups.

BGSUBATTRIT

Matrix; day of campaign by threat submarine type; attrition to threat submarines due battle groups.

BGSUBLOSS

Matrix; threat submarine type by battle group type; attrition to threat submarines due battle groups.

BGVPATTRIT

Matrix; day of campaign by battle group type; attrition to maritime patrol aircraft within battle groups.

CONESCARR

Matrix; day of campaign by convoy type; arrivals of surface escorts within convoys.

CONESCATTRIT

Matrix; day of campaign by convoy type; attrition to surface escorts within convoys.

CONMERARR

Matrix; day of campaign by convoy type; arrivals of merchant ships within convoys.

CONMERATTRIT

Matrix; day of campaign by convoy type; attrition to merchant ships within convoys.

CONSSNARR

Matrix; day of campaign by convoy type; arrivals of attack submarines within convoys.

CONSSNATTRIT

Matrix; day of campaign by convoy type; attrition to attack submarines within convoys.

CONSUBATTRIT

Matrix; day of campaign by threat submarine type; attrition to threat submarines due convoys.

CONSUBLOSS

Matrix; threat submarine type by convoy type; attrition to threat submarines due convoys.

CONVPARR

Matrix; day of campaign by convoy type; "arrivals" of maritime patrol aircraft within convoys.

CONVPATTRIT

Matrix; day of campaign by convoy type; attrition to maritime patrol aircraft within convoys.

INDARR

Matrix; day of campaign by independent shipping type; arrivals of independent ships.

INDATTRIT

Matrix; day of campaign by independent shipping type; attrition to independent ships.

INDSUBATTRIT

Matrix; day of campaign by threat submarine type; attrition to threat submarines due independent shipping.

INDSUBLOSS

Matrix; threat submarine type by independent shipping type; attrition to threat submarines due independent shipping.

MINESUBATTRIT

Matrix; day of campaign by threat submarine type; attrition to threat submarines due mines.

MINESUBLOSS

Matrix; threat submarine type by mine type; attrition to threat submarines due mines.

SSNATTRIT

Matrix; day of campaign by attack submarine type; attrition to attack submarines.

SSNEXCTASM

Vector; by attack submarine type; excess TASMs expended.

SSNEXCTLAM

Vector; by attack submarine type; excess TLAMs expended.

SSNEXCTORP

Vector; by attack submarine type; excess torpedoes expended.

SSNSUBATTRIT

Matrix; day of campaign by threat submarine type; attrition to threat submarines due attack submarines.

SSNSUBLOSS

Matrix; threat submarine type by attack submarine type; attrition to threat submarines due attack submarines.

SUBATTRIT

Matrix; day of campaign by threat submarine type; attrition to threat submarines.

SUBBGCVLOSS

Matrix; threat submarine type by battle group type; attrition to aircraft carriers due threat submarines.

SUBBGESCLOSS

Matrix; threat submarine type by battle group type; attrition to surface escorts within battle groups due threat submarines.

SUBBGSSNLOSS

Matrix; threat submarine type by battle group type; attrition to attack submarines within battle groups due threat submarines.

SUBBGVPLOSS

Matrix; threat submarine type by battle group type; attrition to maritime patrol aircraft within battle groups due threat submarines.

SUBCONESCLOSS

Matrix; threat submarine type by convoy type; attrition to surface escorts within convoys due threat submarines.

SUBCONMERLOSS

Matrix; threat submarine type by convoy type; attrition to merchant ships within convoys due threat submarines.

SUBCONSSNLOSS

Matrix; threat submarine type by convoy type; attrition to attack submarines within convoys due threat submarines.

SUBCONVPLOSS

Matrix; threat submarine type by convoy type; attrition to maritime patrol aircraft within convoys due threat submarines.

SUBEXCSLCM

Vector; by threat submarine type; excess SLCMs expended.

SUBEXCTORP

Vector; by threat submarine type; excess torpedoes expended.

SUBINDLOSS

Matrix; threat submarine type by independent shipping type; attrition to independent ships due threat submarines.

SUBSSNLOSS

Matrix; threat submarine type by attack submarine type; attrition to attack submarines due threat submarines.

SUBURGAUXLOSS

Matrix; threat submarine type by underway replenishment group type; attrition to auxiliary ships due threat submarines.

SUBURGESCLOSS

Matrix; threat submarine type by underway replenishment group type; attrition to surface escorts within underway replenishment groups due threat submarines.

SUBURGSSNLOSS

Matrix; threat submarine type by underway replenishment group type; attrition to attack submarines within underway replenishment groups due threat submarines.

SUBURGVPLOSS

Matrix; threat submarine type by underway replenishment group type; attrition to maritime patrol aircraft within underway replenishment groups due threat submarines.

SUBVPLOSS

Matrix; threat submarine type by maritime patrol aircraft type; attrition to maritime patrol aircraft due threat submarines.

URGAUXARR

Matrix; day of campaign by underway replenishment group type; arrivals of auxiliary ships.

URGAUXATTRIT

Matrix; day of campaign by underway replenishment group type; attrition to auxiliary ships.

URGESCARR

Matrix; day of campaign by underway replenishment group type; arrivals of surface escorts within underway replenishment groups.

URGESCATTRIT

Matrix; day of campaign by underway replenishment group type; attrition to surface escorts within underway replenishment groups.

URGSSNARR

Matrix; day of campaign by underway replenishment group type; arrivals of attack submarines within underway replenishment groups.

URGSSNATTRIT

Matrix; day of campaign by underway replenishment group type; attrition to attack submarines within underway replenishment groups.

URGSUBATTRIT

Matrix; day of campaign by threat submarine type; attrition to threat submarines due underway replenishment groups.

URGSUBLOSS

Matrix; threat submarine type by underway replenishment group type; attrition to threat submarines due underway replenishment groups.

URGVPARR

Matrix; day of campaign by underway replenishment group type; "arrivals" of maritime patrol aircraft within underway replenishment groups.

URGVPATTRIT

Matrix; day of campaign by underway replenishment group type; attrition to maritime patrol aircraft within underway replenishment groups.

VPATTRIT

Matrix; day of campaign by maritime patrol aircraft type; attrition to maritime patrol aircraft.

VPSUBATTRIT

Matrix; day of campaign by threat submarine type; attrition to threat submarines due maritime patrol aircraft.

VPSUBLOSS

Matrix; threat submarine type by maritime patrol aircraft type; attrition to threat submarines due maritime patrol aircraft.

APPENDIX C: CONSTRAINTS ON ATTRITION

The computations, described in II.A, utilized to determine the outcome of interactions between individual elements provide an upper bound on this attrition. The expected attrition to elements may be determined by enumeration of all possible random events for a given set of force levels. However, the large number of combinations of random detections which may exist for a given set of force levels (in addition to an unknown number of different sets of force levels) prohibits these computations within the model.

But if the defined probability of detection is "small", the expected attrition is closely approximated by the upper bound. It can also be shown that a lower bound exists, if an engagement limit equal to one is imposed on the offensive elements, that is not significantly less than the corresponding upper bound. When the probability of detection is "small", this lower bound closely approximates the expected attrition.

Several assumptions are essential to the computations within the model:

1. Detections occur uniformly over the daily time step.
2. Detections occur independently of one another.
3. Given a detection, the target is attacked without undue delay.
4. Limited coordination occurs between offensive elements, as necessary, to avoid duplication of attacks and therefore inflict optimal losses.

The computations and examples herein provided are for the reduced case of one type of offensive element, one type of defensive element, and an imposed limit of one engagement (attack) per offensive element within the daily time step. The theory applied may be expanded to the campaign scenario.

Given an opportunity, an offensive element detects and successfully attacks a defensive element with the probability, PD x PK. If all offensive elements attack an individual defensive element, the target survives with the probability:

$$(1 - PDxPK)^M$$

where:

M: Number of offensive elements

PD: Probability of detection

PK: Probability of kill given detection

Or, the probability that an individual defensive element is successfully attacked is:

$$1 - (1 - PDxPK)^M$$

Given that there are N defensive elements (or targets), the number of defensive elements successfully attacked is then approximated by:

$$N \times (1 - (1 - PDxPK)^M)$$

This approximation yields an upper bound on the attrition since all offensive elements attack each defensive element, and no constraint is imposed on the number of engagements by each offensive element. Also, this expected-value approximation as derived by Helmbold provides better estimates than most other approximation schemes over a wide range of parameter values [HELMBOLD, 1966].

The attrition to the defensive elements is determined by the minimum of two upper bounds. One constraint, as just described, reflects both the probability of detection and the probability of kill given detection:

$$U1 = N \times (1 - (1 - PDxPK)^M)$$

The second constraint considers the limit on engagements per offensive element within the daily time step.

$$U2 = M \times PK \times E$$

where:

E: Maximum number of engagements for each offensive element within the daily time step.

Attrition to the defensive elements is equal to the minimum of the two upper bounds, U1 and U2 (that is, for the computations within this campaign model). The minimum of these two upper bounds remains to be an upper bound on the attrition.

However, the accuracy of this upper bound as an approximation to the expected attrition is not certain. If a lower bound can be established that does not differ significantly from the upper bound, the (upper bound) approximation may then be acceptable.

If the limit on engagements is assumed to be one, a lower bound to this attrition is provided by [HELMBOLD]:

$$L = N \times \left(1 - \left(1 - \frac{PKx(1 - (1-PD)^N)}{N}\right)^M\right)$$

Given an opportunity, an offensive element detects at least one defensive element with the probability:

$$(1 - (1 - PD)^N)$$

or, the probability that an offensive element fails to detect any defensive elements is:

$$(1 - PD)^N$$

Assuming a limit of one engagement by each offensive element within the daily time step, the probability that an offensive element successfully attacks a defensive element is:

$$PK \times (1 - (1 - PD)^N)$$

Then the probability that a given offensive element successfully attacks a given defensive element is:

$$PK \times (1 - (1 - PD)^N)/N$$

Substitution of this probability of kill for the expression PDxPK in the equation for U1, an upper bound, yields the lower bound previously stated.

Now if the probability of detection is "small",

$$U1 \doteq N \times (1 - (1 - MxPDxPK)) \doteq NxMxPDxPK$$

and

$$L \doteq N \times (1 - (1 - M \times \frac{PKx(NxPD)}{N})) \doteq NxMxPDxPK$$

If the expected attrition can be approximated by:

$$(L + Min(U1,U2))/2$$

Then the expected attrition is approximated by:

$$N \times M \times PD \times PK$$

for "small" probability of detection, PD. (That is, for a "small" probability of detection, the upper and lower bounds are approximately equal.)

If the engagement limit is not one, determination of an appropriate lower bound is more difficult. The upper bound to the attrition is therefore used within the campaign model.

Consider the following numerical example where:

$N = 2$

$M = 2$

$PD = 0.5$ (not "small")

$PK = 1.0$

Then $U1 = 1.5$ and $U2 = 2.0$; the attrition to the defensive elements as determined by the minimum of the two upper bounds is 1.5 elements. The lower bound provides an estimate of attrition equal to 1.21875 elements.

Enumeration of the 16 possible combinations of random detections yields an expected attrition of 1.375 elements in accordance with the stated assumptions. This attrition is ascertained by determining the probability of each event occurring and weighting it by the corresponding expected loss of defensive elements. The upper and lower bounds bracket the expected attrition, and do not differ "significantly".

$L < E(\text{Attrition}) < \text{Min}(U1, U2)$

$1.21875 < 1.375 < 1.5$

$(L + \text{Min}(U1, U2))/2 = 1.359375$

As the probability of detection becomes "small", the difference between these bounds further decreases and the accuracy of the approximation increases.

This campaign model provides but a moderately good description of the real world. The decision to use an approximation to the attrition is then acceptable and advantageous. This approach greatly reduces the required computational effort, and provides "a clearer view of how the attrition process responds to changes in the basic parameters" [HELMBOLD].

[illegible]

```
      ∇CAMPAIGN[⎕]∇
    ∇ CAMPAIGN
[1]   ⍝   COMMENTS PRECEDE APPLICABLE FUNCTION LINE.
[2]   DAY←0
[3]   SUBATTRIT←(⌽⍴SUBSKED)⍴0
[4]   SSNATTRIT←(⌽⍴SSNSKED)⍴0
[5]   INDATTRIT←(⌽⍴INDSKED)⍴0
[6]   CONVPATTRIT←(⌽⍴CONSKED)⍴0
[7]   CONSSNATTRIT←(⌽⍴CONSKED)⍴0
[8]   CONESCATTRIT←(⌽⍴CONSKED)⍴0
[9]   CONMERATTRIT←(⌽⍴CONSKED)⍴0
[10]  URGVPATTRIT←(⌽⍴URGSKED)⍴0
[11]  URGSSNATTRIT←(⌽⍴URGSKED)⍴0
[12]  URGESCATTRIT←(⌽⍴URGSKED)⍴0
[13]  URGAUXATTRIT←(⌽⍴URGSKED)⍴0
[14]  BGVPATTRIT←(⌽⍴BGSKED)⍴0
[15]  BGSSNATTRIT←(⌽⍴BGSKED)⍴0
[16]  BGESCATTRIT←(⌽⍴BGSKED)⍴0
[17]  BGCVATTRIT←(⌽⍴BGSKED)⍴0
[18]  VPATTRIT←((¯1↑⍴SUBSKED),1↑⍴VPQTY)⍴0
[19]  SSNSUBATTRIT←(⌽⍴SUBSKED)⍴0
[20]  INDSUBATTRIT←(⌽⍴SUBSKED)⍴0
[21]  CONSUBATTRIT←(⌽⍴SUBSKED)⍴0
[22]  URGSUBATTRIT←(⌽⍴SUBSKED)⍴0
[23]  BGSUBATTRIT←(⌽⍴SUBSKED)⍴0
[24]  VPSUBATTRIT←(⌽⍴SUBSKED)⍴0
[25]  MINESUBATTRIT←(⌽⍴SUBSKED)⍴0
[26]  AREASUBLOSS←(AREAQTY,1↑⍴SUBQTY)⍴0
[27]  AREASSNLOSS←(AREAQTY,1↑⍴SSNQTY)⍴0
[28]  AREAINDLOSS←(AREAQTY,1↑⍴INDQTY)⍴0
[29]  AREACONVPLOSS←(AREAQTY,1↑⍴CONSKED)⍴0
```

```
[30]  AREACONSSNLOSS←(AREAQTY,1↑ρCONSKED)ρ0
[31]  AREACONESCLOSS←(AREAQTY,1↑ρCONSKED)ρ0
[32]  AREACONMERLOSS←(AREAQTY,1↑ρCONSKED)ρ0
[33]  AREAURGVPLOSS←(AREAQTY,1↑ρURGSKED)ρ0
[34]  AREAURGSSNLOSS←(AREAQTY,1↑ρURGSKED)ρ0
[35]  AREAURGESCLOSS←(AREAQTY,1↑ρURGSKED)ρ0
[36]  AREAURGAUXLOSS←(AREAQTY,1↑ρURGSKED)ρ0
[37]  AREABGVPLOSS←(AREAQTY,1↑ρBGSKED)ρ0
[38]  AREABGSSNLOSS←(AREAQTY,1↑ρBGSKED)ρ0
[39]  AREABGESCLOSS←(AREAQTY,1↑ρBGSKED)ρ0
[40]  AREABGCVLOSS←(AREAQTY,1↑ρBGSKED)ρ0
[41]  AREAVPLOSS←(ΦρVPQTY)ρ0
[42]  AREAVPSUBLOSS←(AREAQTY,1↑ρSUBQTY)ρ0
[43]  AREASSNSUBLOSS←(AREAQTY,1↑ρSUBQTY)ρ0
[44]  AREAINDSUBLOSS←(AREAQTY,1↑ρSUBQTY)ρ0
[45]  AREACONSUBLOSS←(AREAQTY,1↑ρSUBQTY)ρ0
[46]  AREAURGSUBLOSS←(AREAQTY,1↑ρSUBQTY)ρ0
[47]  AREABGSUBLOSS←(AREAQTY,1↑ρSUBQTY)ρ0
[48]  AREAMINESUBLOSS←(AREAQTY,1↑ρSUBQTY)ρ0
[49]  SUBSSNLOSS←((1↑ρSUBQTY),1↑ρSSNQTY)ρ0
[50]  SUBINDLOSS←((1↑ρSUBQTY),1↑ρINDQTY)ρ0
[51]  SUBCONVPLOSS←((1↑ρSUBQTY),1↑ρCONSKED)ρ0
[52]  SUBCONSSNLOSS←((1↑ρSUBQTY),1↑ρCONSKED)ρ0
[53]  SUBCONESCLOSS←((1↑ρSUBQTY),1↑ρCONSKED)ρ0
[54]  SUBCONMERLOSS←((1↑ρSUBQTY),1↑ρCONSKED)ρ0
[55]  SUBURGVPLOSS←((1↑ρSUBQTY),1↑ρURGSKED)ρ0
[56]  SUBURGSSNLOSS←((1↑ρSUBQTY),1↑ρURGSKED)ρ0
[57]  SUBURGESCLOSS←((1↑ρSUBQTY),1↑ρURGSKED)ρ0
[58]  SUBURGAUXLOSS←((1↑ρSUBQTY),1↑ρURGSKED)ρ0
[59]  SUBBGVPLOSS←((1↑ρSUBQTY),1↑ρBGSKED)ρ0
[60]  SUBBGSSNLOSS←((1↑ρSUBQTY),1↑ρBGSKED)ρ0
[61]  SUBBGESCLOSS←((1↑ρSUBQTY),1↑ρBGSKED)ρ0
[62]  SUBBGCVLOSS←((1↑ρSUBQTY),1↑ρBGSKED)ρ0
[63]  SUBVPLOSS←((1↑ρSUBQTY),1↑ρVPQTY)ρ0
[64]  SSNSUBLOSS←((1↑ρSUBQTY),1↑ρSSNQTY)ρ0
[65]  INDSUBLOSS←((1↑ρSUBQTY),1↑ρINDQTY)ρ0
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[66]  CONSUBLOSS←((1↑ρSUBQTY),1↑ρCONAREA)ρ0
[67]  URGSUBLOSS←((1↑ρSUBQTY),1↑ρURGAREA)ρ0
[68]  BGSUBLOSS←((1↑ρSUBQTY),1↑ρBGAREA)ρ0
[69]  VPSUBLOSS←((1↑ρSUBQTY),1↑ρVPQTY)ρ0
[70]  MINESUBLOSS←((1↑ρSUBQTY),1↑ρMINEQTY)ρ0
[71]  SUBINIT←(+/SUBQTY)++/SUBSKED
[72]  SSNINIT←(+/SSNQTY)++/SSNSKED
[73]  INDINIT←(+/INDQTY)++/INDSKED
[74]  CONMERINIT←(+/CONMERQTY)++/CONSKED
[75]  URGAUXINIT←(+/URGAUXQTY)++/URGSKED
[76]  BGCVINIT←(+/BGCVQTY)++/BGSKED
[77]  VPINIT←+/VPQTY
[78]  INDARR←(ΦρINDSKED)ρ0
[79]  CONVPARR←(ΦρCONSKED)ρ0
[80]  CONSSNARR←(ΦρCONSKED)ρ0
[81]  CONESCARR←(ΦρCONSKED)ρ0
[82]  CONMERARR←(ΦρCONSKED)ρ0
[83]  URGVPARR←(ΦρURGSKED)ρ0
[84]  URGSSNARR←(ΦρURGSKED)ρ0
[85]  URGESCARR←(ΦρURGSKED)ρ0
[86]  URGAUXARR←(ΦρURGSKED)ρ0
[87]  SUBTORP←SUBQTY×⍉(ΦρSUBQTY)ρSUBTORPLOAD
[88]  SUBSLCM←SUBQTY×⍉(ΦρSUBQTY)ρSUBSLCMLOAD
[89]  SSNTORP←SSNQTY×⍉(ΦρSSNQTY)ρSSNTORPLOAD
[90]  SSNTLAM←SSNQTY×⍉(ΦρSSNQTY)ρSSNTLAMLOAD
[91]  SSNTASM←SSNQTY×⍉(ΦρSSNQTY)ρSSNTASMLOAD
[92]  SUBEXCTORP←(1↑ρSUBQTY)ρ0
[93]  SUBEXCSLCM←(1↑ρSUBQTY)ρ0
[94]  SSNEXCTORP←(1↑ρSSNQTY)ρ0
[95]  SSNEXCTLAM←(1↑ρSSNQTY)ρ0
[96]  SSNEXCTASM←(1↑ρSSNQTY)ρ0
[97]  FLGDAT←(1↑ρSUBQTY)ρ0
[98] NEXTDAY:DAY←DAY+1
[99]  →ADVANCE×⍳DAYOFF=1
[100] DAY
[101]ADVANCE:ENDSUB←SUBQTY×((ρSUBQTY)ρ⍳¯1↑ρSUBQTY)=⍉(ΦρSUBQTY)ρSUBEND
```

```
[102] SUBQTY←SUBQTY-ENDSUB
[103] SUBTORP←SUBTORP×SUBQTY>0
[104] SUBSLCM←SUBSLCM×SUBQTY>0
[105] SUBQTY[;¯1↑ρSUBQTY]←+/ENDSUB
[106] SUBQTY←¯1⌽SUBQTY
[107] SUBTORP←¯1⌽SUBTORP
[108] SUBSLCM←¯1⌽SUBSLCM
[109] SUBQTY[;1]←SUBQTY[;1]+SUBSKED[;DAY]
[110] SUBTORP[;1]←SUBQTY[;1]×SUBTORPLOAD
[111] SUBSLCM[;1]←SUBQTY[;1]×SUBSLCMLOAD
[112] ENDSUBOAR←SUBOARQTY×((ρSUBOARQTY)ρι¯1↑ρSUBOARQTY)=⍉(⌽ρSUBOARQTY)ρSUBOAREND
[113] SUBOARQTY←SUBOARQTY-ENDSUBOAR
[114] ENDSUBOAR←(((ρSUBQTY)ρι¯1↑ρSUBQTY)=⍉(⌽ρSUBQTY)ρSUBON)×⍉(⌽ρSUBQTY)ρ+/ENDSUBOA≥
R
[115] SUBQTY←SUBQTY+ENDSUBOAR
[116] SUBTORP←SUBTORP+ENDSUBOAR×⍉(⌽ρENDSUBOAR)ρSUBTORPLOAD
[117] SUBSLCM←SUBSLCM+ENDSUBOAR×⍉(⌽ρENDSUBOAR)ρSUBSLCMLOAD
[118] SUBOARQTY←¯1⌽SUBOARQTY
[119] ONSUB←SUBQTY×((ρSUBQTY)ρι¯1↑ρSUBQTY)<⍉(⌽ρSUBQTY)ρSUBOFF
[120] SUBWOW←ONSUB×(SUBTORP≤⍉(⌽ρSUBTORP)ρZEROSUBTORP)∧SUBSLCM≤⍉(⌽ρSUBSLCM)ρZEROSUB≥
SLCM
[121] SUBQTY←SUBQTY-SUBWOW
[122] SUBTORP←SUBTORP×SUBQTY>0
[123] SUBSLCM←SUBSLCM×SUBQTY>0
[124] OFFWOW←((ρSUBQTY)ρ+/SUBWOW)×((ρSUBQTY)ρι¯1↑ρSUBQTY)=⍉(⌽ρSUBQTY)ρSUBOFF
[125] SUBQTY←SUBQTY+OFFWOW
[126] OFFSUB←SUBQTY×((ρSUBQTY)ρι¯1↑ρSUBQTY)=⍉(⌽ρSUBQTY)ρSUBOFF
[127] OFFTORP←SUBTORP×OFFSUB>0
[128] OFFSLCM←SUBSLCM×OFFSUB>0
[129] SUBQTY←SUBQTY-OFFSUB
[130] SUBTORP←SUBTORP-OFFTORP
[131] SUBSLCM←SUBSLCM-OFFSLCM
[132] SUBOARQTY[;1]←SUBPCTOAR×+/OFFSUB
[133] OFFSUB←OFFSUB×⍉(⌽ρOFFSUB)ρ1-SUBPCTOAR
[134] OFFTORP←OFFTORP×⍉(⌽ρOFFTORP)ρ1-SUBPCTOAR
[135] OFFSLCM←OFFSLCM×⍉(⌽ρOFFSLCM)ρ1-SUBPCTOAR
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[136] SUBQTY←SUBQTY+OFFSUB
[137] SUBTORP←SUBTORP+OFFTORP
[138] SUBSLCM←SUBSLCM+OFFSLCM
[139] ENDSSN←SSNQTY×((ρSSNQTY)ρι¯1↑ρSSNQTY)=⍉(⌽ρSSNQTY)ρSSNEND
[140] SSNQTY←SSNQTY−ENDSSN
[141] SSNTORP←SSNTORP×SSNQTY>0
[142] SSNTLAM←SSNTLAM×SSNQTY>0
[143] SSNTASM←SSNTASM×SSNQTY>0
[144] SSNQTY[;¯1↑ρSSNQTY]←+/ENDSSN
[145] SSNQTY←¯1⌽SSNQTY
[146] SSNTORP←¯1⌽SSNTORP
[147] SSNTLAM←¯1⌽SSNTLAM
[148] SSNTASM←¯1⌽SSNTASM
[149] SSNQTY[;1]←SSNQTY[;1]+SSNSKED[;DAY]
[150] SSNTORP[;1]←SSNQTY[;1]×SSNTORPLOAD
[151] SSNTLAM[;1]←SSNQTY[;1]×SSNTLAMLOAD
[152] SSNTASM[;1]←SSNQTY[;1]×SSNTASMLOAD
[153] ENDSSNOAR←SSNOARQTY×((ρSSNOARQTY)ρι¯1↑ρSSNOARQTY)=⍉(⌽ρSSNOARQTY)ρSSNOAREND
[154] SSNOARQTY←SSNOARQTY−ENDSSNOAR
[155] ENDSSNOAR←(((ρSSNQTY)ρι¯1↑ρSSNQTY)=⍉(⌽ρSSNQTY)ρSSNON)×⍉(⌽ρSSNQTY)ρ+/ENDSSNOA≥
R
[156] SSNQTY←SSNQTY+ENDSSNOAR
[157] SSNTORP←SSNTORP+ENDSSNOAR×⍉(⌽ρENDSSNOAR)ρSSNTORPLOAD
[158] SSNTLAM←SSNTLAM+ENDSSNOAR×⍉(⌽ρENDSSNOAR)ρSSNTLAMLOAD
[159] SSNTASM←SSNTASM+ENDSSNOAR×⍉(⌽ρENDSSNOAR)ρSSNTASMLOAD
[160] SSNOARQTY←¯1⌽SSNOARQTY
[161] ONSSN←SSNQTY×((ρSSNQTY)ρι¯1↑ρSSNQTY)<⍉(⌽ρSSNQTY)ρSSNOFF
[162] SSNWOW←ONSSN×(SSNTORP≤⍉(⌽ρSSNTORP)ρZEROSSNTORP)∧(SSNTLAM≤⍉(⌽ρSSNTLAM)ρZEROSS≥
NTLAM)∧SSNTASM≤⍉(⌽ρSSNTASM)ρ
      ZEROSSNTASM
[163] SSNQTY←SSNQTY−SSNWOW
[164] SSNTORP←SSNTORP×SSNQTY>0
[165] SSNTLAM←SSNTLAM×SSNQTY>0
[166] SSNTASM←SSNTASM×SSNQTY>0
[167] OFFWOW←((ρSSNQTY)ρ+/SSNWOW)×((ρSSNQTY)ρι¯1↑ρSSNQTY)=⍉(⌽ρSSNQTY)ρSSNOFF
[168] SSNQTY←SSNQTY+OFFWOW
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[169] OFFSSN←SSNQTY×((ρSSNQTY)ρι¯1↑ρSSNQTY)=⍉(⌽ρSSNQTY)ρSSNOFF
[170] OFFTORP←SSNTORP×OFFSSN>0
[171] OFFTLAM←SSNTLAM×OFFSSN>0
[172] OFFTASM←SSNTASM×OFFSSN>0
[173] SSNQTY←SSNQTY-OFFSSN
[174] SSNTORP←SSNTORP-OFFTORP
[175] SSNTLAM←SSNTLAM-OFFTLAM
[176] SSNTASM←SSNTASM-OFFTASM
[177] SSNOARQTY[;1]←SSNPCTOAR×+/OFFSSN
[178] OFFSSN←OFFSSN×⍉(⌽ρOFFSSN)ρ1-SSNPCTOAR
[179] OFFTORP←OFFTORP×⍉(⌽ρOFFTORP)ρ1-SSNPCTOAR
[180] OFFTLAM←OFFTLAM×⍉(⌽ρOFFTLAM)ρ1-SSNPCTOAR
[181] OFFTASM←OFFTASM×⍉(⌽ρOFFTASM)ρ1-SSNPCTOAR
[182] SSNQTY←SSNQTY+OFFSSN
[183] SSNTORP←SSNTORP+OFFTORP
[184] SSNTLAM←SSNTLAM+OFFTLAM
[185] SSNTASM←SSNTASM+OFFTASM
[186] ENDIND←INDQTY×((ρINDQTY)ρι¯1↑ρINDQTY)=⍉(⌽ρINDQTY)ρINDEND
[187] INDQTY←INDQTY-ENDIND
[188] INDARR[DAY;]←+/ENDIND
[189] INDQTY←¯1⌽INDQTY
[190] INDQTY[;1]←INDSKED[;DAY]
[191] ENDCON←((ρCONAREA)ρι¯1↑ρCONAREA)=⍉(⌽ρCONAREA)ρCONEND
[192] ENDCONVP←CONVPQTY×ENDCON
[193] CONVPQTY←CONVPQTY-ENDCONVP
[194] CONVPARR[DAY;]←+/ENDCONVP
[195] CONVPQTY←¯1⌽CONVPQTY
[196] ENDCONSSN←CONSSNQTY×ENDCON
[197] CONSSNQTY←CONSSNQTY-ENDCONSSN
[198] CONSSNARR[DAY;]←+/ENDCONSSN
[199] CONSSNQTY←¯1⌽CONSSNQTY
[200] ENDCONESC←CONESCQTY×ENDCON
[201] CONESCQTY←CONESCQTY-ENDCONESC
[202] CONESCARR[DAY;]←+/ENDCONESC
[203] CONESCQTY←¯1⌽CONESCQTY
[204] ENDCONMER←CONMERQTY×ENDCON
```

```
[205] CONMERQTY←CONMERQTY-ENDCONMER
[206] CONMERARR[DAY;]←+/ENDCONMER
[207] CONMERQTY←¯1ΦCONMERQTY
[208] CONMERQTY[;1]←CONSKED[;DAY]
[209] VP←1
[210] SSN←2
[211] ESC←3
[212] CONVPQTY[;1]←CONSCREEN[;VP]×CONMERQTY[;1]>0
[213] CONSSNQTY[;1]←CONSCREEN[;SSN]×CONMERQTY[;1]>0
[214] CONESCQTY[;1]←CONSCREEN[;ESC]×CONMERQTY[;1]>0
[215] ENDURG←((ρURGAREA)ρι¯1↑ρURGAREA)=⍉(ΦρURGAREA)ρURGEND
[216] ENDURGVP←URGVPQTY×ENDURG
[217] URGVPQTY←URGVPQTY-ENDURGVP
[218] URGVPARR[DAY;]←+/ENDURGVP
[219] URGVPQTY←¯1ΦURGVPQTY
[220] URGVPQTY[;1]←+/ENDURGVP
[221] ENDURGSSN←URGSSNQTY×ENDURG
[222] URGSSNQTY←URGSSNQTY-ENDURGSSN
[223] URGSSNARR[DAY;]←+/ENDURGSSN
[224] URGSSNQTY←¯1ΦURGSSNQTY
[225] URGSSNQTY[;1]←+/ENDURGSSN
[226] ENDURGESC←URGESCQTY×ENDURG
[227] URGESCQTY←URGESCQTY-ENDURGESC
[228] URGESCARR[DAY;]←+/ENDURGESC
[229] URGESCQTY←¯1ΦURGESCQTY
[230] URGESCQTY[;1]←+/ENDURGESC
[231] ENDURGAUX←URGAUXQTY×ENDURG
[232] URGAUXQTY←URGAUXQTY-ENDURGAUX
[233] URGAUXARR[DAY;]←+/ENDURGAUX
[234] URGAUXQTY←¯1ΦURGAUXQTY
[235] URGAUXQTY[;1]←+/ENDURGAUX
[236] URGAUXQTY[;1]←URGAUXQTY[;1]+URGSKED[;DAY]
[237] URGVPQTY[;1]←URGVPQTY[;1]+URGSCREEN[;VP]×URGSKED[;DAY]>0
[238] URGSSNQTY[;1]←URGSSNQTY[;1]+URGSCREEN[;SSN]×URGSKED[;DAY]>0
[239] URGESCQTY[;1]←URGESCQTY[;1]+URGSCREEN[;ESC]×URGSKED[;DAY]>0
[240] ENDBG←((ρBGAREA)ρι¯1↑ρBGAREA)=⍉(ΦρBGAREA)ρBGEND
```

```
 ENDBGVP←BGVPQTY×ENDBG
 BGVPQTY←BGVPQTY-ENDBGVP
 BGVPQTY←¯1⌽BGVPQTY
 BGVPQTY[;1]←+/ENDBGVP
 ENDBGSSN←BGSSNQTY×ENDBG
 BGSSNQTY←BGSSNQTY-ENDBGSSN
 BGSSNQTY←¯1⌽BGSSNQTY
 BGSSNQTY[;1]←+/ENDBGSSN
 ENDBGESC←BGESCQTY×ENDBG
 BGESCQTY←BGESCQTY-ENDBGESC
 BGESCQTY←¯1⌽BGESCQTY
 BGESCQTY[;1]←+/ENDBGESC
 ENDBGCV←BGCVQTY×ENDBG
 BGCVQTY←BGCVQTY-ENDBGCV
 BGCVQTY←¯1⌽BGCVQTY
 BGCVQTY[;1]←+/ENDBGCV
 BGCVQTY[;1]←BGCVQTY[;1]+BGSKED[;DAY]
 BGVPQTY[;1]←BGVPQTY[;1]+BGSCREEN[;VP]×BGSKED[;DAY]>0
 BGSSNQTY[;1]←BGSSNQTY[;1]+BGSCREEN[;SSN]×BGSKED[;DAY]>0
 BGESCQTY[;1]←BGESCQTY[;1]+BGSCREEN[;ESC]×BGSKED[;DAY]>0
 →CONTINUE×⍳DAY≠PAUSE
 'CAMPAIGN AT BEGINNING OF DAY ';DAY
 'TO RESUME EXECUTION, TYPE:  →RESUME'
 S∆CAMPAIGN←RESUME
RESUME:'ENTER DAY OF NEXT PAUSE'
 PAUSE←⎕
CONTINUE:AREA←0
NEXTAREA:AREA←AREA+1
 AREASUB←SUBQTY×SUBAREA=AREA
 SUBQTY←SUBQTY-AREASUB
 AREASUBTORP←SUBTORP×SUBAREA=AREA
 SUBTORP←SUBTORP-AREASUBTORP
 AREASUBSLCM←SUBSLCM×SUBAREA=AREA
 SUBSLCM←SUBSLCM-AREASUBSLCM
 AREASUBOAR←SUBOARQTY×SUBOARAREA=AREA
 SUBOARQTY←SUBOARQTY-AREASUBOAR
```

```
⍝    INSERT PLATFORM FUNCTIONS HERE
ATTACKSUBMARINE
MINES
INDEPSHIP
PATROLAIRCRAFT
BATTLEGROUP
UNREPGROUP
CONVOY
SUBSLCM←SUBSLCM+AREASUBSLCM
SUBTORP←SUBTORP+AREASUBTORP
SUBOARQTY←SUBOARQTY+AREASUBOAR
SUBQTY←SUBQTY+AREASUB
→NEXTAREA×⍳AREA<AREAQTY
→NEXTDAY×⍳DAY<DURATION
'CAMPAIGN COMPLETED'
∇
```

```
    ∇ATTACKSUBMARINE[⎕]∇
  ∇ ATTACKSUBMARINE
[1]   AREASSN←SSNQTY×SSNAREA=AREA
[2]   AREASSN←AREASSN×SSNTORP>0
[3]   →0×⍳0=+/+/AREASSN
[4]   SSNQTY←SSNQTY-AREASSN
[5]   →OTHERATTRIT×⍳0=+/+/AREASUB
[6]   SUBSUNK←(+/AREASUB)×1-×/(1-SSNPDETSUB[AREA;;]×SSNPKILLSUB[AREA;;])*(⍴SSNPKILLSUB[
      AREA;;])⍴+/AREASSN
[7]   SSNPK←1-(1-SSNPDETSUB[AREA;;]×SSNPKILLSUB[AREA;;])*(⍴SSNPKILLSUB[AREA;;])⍴+/AREASSN
[8]   SUBLOSS←(⍉(⌽⍴SSNPK)⍴SUBSUNK)×SSNPK÷⍉(⌽⍴SSNPK)⍴+/SSNPK
[9]   ENGAGE←SUBLOSS×1÷SSNPKILLSUB[AREA;;]
[10]  ENGAGE←ENGAGE×(⍴ENGAGE)⍴((+⌿ENGAGE)⌊SSNSUBENGLMT×+/AREASSN)÷+⌿ENGAGE
[11]  SUBLOSS←ENGAGE×SSNPKILLSUB[AREA;;]
[12]  SUBSUNK←+/SUBLOSS
[13]  SSNLOST←(+/AREASSN)×1-×⌿(1-SUBPKILLSSN[AREA;;])*ENGAGE÷(⍴ENGAGE)⍴+/AREASSN
[14]  SUBPK←1-(1-SUBPKILLSSN[AREA;;])*ENGAGE÷(⍴ENGAGE)⍴+/AREASSN
[15]  SSNLOSS←((⍴SUBPK)⍴SSNLOST)×SUBPK÷(⍴SUBPK)⍴+⌿SUBPK
[16]  SSNTORPEXP←+⌿SSNTORPPERSUB×ENGAGE
[17]  SSNTORP←SSNTORP-AREASSN×⍉(⌽⍴AREASSN)⍴SSNTORPEXP÷+/AREASSN
[18]  EXCESSTORP←+/SSNTORP×SSNTORP<0
[19]  SSNEXCTORP←SSNEXCTORP+EXCESSTORP
[20]  SSNTORP←SSNTORP×SSNTORP>0
[21]  SUBTORPEXP←+/SUBTORPPERSSN×SSNLOSS×1÷SUBPKILLSSN[AREA;;]
[22]  AREASUBTORP←AREASUBTORP-AREASUB×⍉(⌽⍴AREASUB)⍴SUBTORPEXP÷+/AREASUB
[23]  EXCESSTORP←+/AREASUBTORP×AREASUBTORP<0
[24]  SUBEXCTORP←SUBEXCTORP+EXCESSTORP
[25]  AREASUBTORP←AREASUBTORP×AREASUBTORP>0
[26]  PCTSUBSURV←⍉(⌽⍴AREASUB)⍴1-SUBSUNK÷+/AREASUB
[27]  AREASUBTORP←AREASUBTORP×PCTSUBSURV
[28]  AREASUBSLCM←AREASUBSLCM×PCTSUBSURV
[29]  AREASUB←AREASUB×PCTSUBSURV
[30]  SUBATTRIT[DAY;]←SUBATTRIT[DAY;]+SUBSUNK
[31]  SSNSUBATTRIT[DAY;]←SSNSUBATTRIT[DAY;]+SUBSUNK
[32]  AREASUBLOSS[AREA;]←AREASUBLOSS[AREA;]+SUBSUNK
[33]  AREASSNSUBLOSS[AREA;]←AREASSNSUBLOSS[AREA;]+SUBSUNK
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[34]  SSNSUBLOSS←SSNSUBLOSS+SUBLOSS
[35]  PCTSSNSUNK←⍉(⌽⍴AREASSN)⍴SSNLOST÷+/AREASSN
[36]  SSNTORP←SSNTORP-PCTSSNSUNK×SSNTORP×AREASSN>0
[37]  SSNTLAM←SSNTLAM-PCTSSNSUNK×SSNTLAM×AREASSN>0
[38]  SSNTASM←SSNTASM-PCTSSNSUNK×SSNTASM×AREASSN>0
[39]  AREASSN←AREASSN×1-PCTSSNSUNK
[40]  SSNATTRIT[DAY;]←SSNATTRIT[DAY;]+SSNLOST
[41]  AREASSNLOSS[AREA;]←AREASSNLOSS[AREA;]+SSNLOST
[42]  SUBSSNLOSS←SUBSSNLOSS+SSNLOSS
[43] OTHERATTRIT:OTHERSSNLOST←AREASSN×⍉(⌽⍴AREASSN)⍴OTHERPKSSN[;AREA]
[44]  AREASSN←AREASSN-OTHERSSNLOST
[45]  SSNQTY←SSNQTY+AREASSN
[46]  SSNATTRIT[DAY;]←SSNATTRIT[DAY;]++/OTHERSSNLOST
    ∇
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      ∇BATTLEGROUP[⎕]∇
    ∇ BATTLEGROUP
[1]   AREABGCV←BGCVQTY×BGAREA=AREA
[2]   →0×⍳0=+/+/AREABGCV
[3]   BGCVQTY←BGCVQTY-AREABGCV
[4]   AREABGVP←BGVPQTY×AREABGCV>0
[5]   BGVPQTY←BGVPQTY-AREABGVP
[6]   AREABGSSN←BGSSNQTY×AREABGCV>0
[7]   BGSSNQTY←BGSSNQTY-AREABGSSN
[8]   AREABGESC←BGESCQTY×AREABGCV>0
[9]   BGESCQTY←BGESCQTY-AREABGESC
[10]  →OTHERATTRIT×⍳0=+/+/AREASUB
[11]  AREASUBTSK←AREASUB×⍉(⌽⍴AREASUB)⍴SUBTASKBG
[12]  AREASUBTSK←AREASUBTSK×(AREASUBTORP>0)∨AREASUBSLCM>0
[13]  VP←1
[14]  SSN←2
[15]  ESC←3
[16]  CV←4
[17]  BGFPINDEX←AREABGVP×⍉(⌽⍴AREABGVP)⍴BGFPSCORE[;VP]
[18]  BGFPINDEX←BGFPINDEX+AREABGSSN×⍉(⌽⍴AREABGSSN)⍴BGFPSCORE[;SSN]
[19]  BGFPINDEX←BGFPINDEX+AREABGESC×⍉(⌽⍴AREABGESC)⍴BGFPSCORE[;ESC]
[20]  BGFPINDEX←BGFPINDEX+AREABGCV×⍉(⌽⍴AREABGCV)⍴BGFPSCORE[;CV]
[21]  BGFPPCT←BGFPINDEX÷⍉(⌽⍴BGFPINDEX)⍴REFBGFPINDEX
[22]  ENGAGE←(⍉(⌽⍴SUBPENGBG[AREA;;])⍴+/AREASUBTSK)×SUBPENGBG[AREA;;]×(⍴SUBPENGBG[AREA;≥
;])
      ⍴+/AREABGCV>0
[23]  ENGAGE←ENGAGE×⍉(⌽⍴ENGAGE)⍴((+/ENGAGE)⌊SUBBGENGLMT×+/AREASUBTSK)÷+/ENGAGE
[24]  ENGPERBG←ENGAGE÷(⍴ENGAGE)⍴+/AREABGCV>0
[25]  SIZE←((1↑⍴SUBAREA)×1↑⍴BGAREA),¯1↑⍴BGAREA
[26]  EXPENGMT←(⍉(⌽SIZE)⍴ENGPERBG)×SIZE⍴AREABGCV>0
[27]  TORP←5
[28]  SLCM←6
[29]  SUB←7
[30]  VPEXPLOSS←(⍉(⌽SIZE)⍴BGEXPLOSS[;VP])×((SIZE⍴BGFPPCT)*⍉(⌽SIZE)⍴BGEXP[;VP])×EXP≥
ENGMT
[31]  PAGE←(1↑⍴SUBAREA),⍴BGAREA
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[32]  VPEXPLOSS←VPEXPLOSS×SIZEρ(AREABGVP⌊+⌿PAGEρVPEXPLOSS)÷+⌿PAGEρVPEXPLOSS
[33]  AREABGVP←AREABGVP-+⌿PAGEρVPEXPLOSS
[34]  BGVPLOSS←(ρENGAGE)ρ+/VPEXPLOSS
[35]  BGVPLOST←+⌿BGVPLOSS
[36]  AREABGVPLOSS[AREA;]←AREABGVPLOSS[AREA;]+BGVPLOST
[37]  SUBBGVPLOSS←SUBBGVPLOSS+BGVPLOSS
[38]  BGVPATTRIT[DAY;]←BGVPATTRIT[DAY;]+BGVPLOST
[39]  SSNEXPLOSS←(⍉(⌽SIZE)ρBGEXPLOSS[;SSN])×((SIZEρBGFPPCT)*⍉(⌽SIZE)ρBGEXP[;SSN])×
      EXPENGMT
[40]  SSNEXPLOSS←SSNEXPLOSS×SIZEρ(AREABGSSN⌊+⌿PAGEρSSNEXPLOSS)÷+⌿PAGEρSSNEXPLOSS
[41]  AREABGSSN←AREABGSSN-+⌿PAGEρSSNEXPLOSS
[42]  BGSSNLOSS←(ρENGAGE)ρ+/SSNEXPLOSS
[43]  BGSSNLOST←+⌿BGSSNLOSS
[44]  AREABGSSNLOSS[AREA;]←AREABGSSNLOSS[AREA;]+BGSSNLOST
[45]  SUBBGSSNLOSS←SUBBGSSNLOSS+BGSSNLOSS
[46]  BGSSNATTRIT[DAY;]←BGSSNATTRIT[DAY;]+BGSSNLOST
[47]  ESCEXPLOSS←(⍉(⌽SIZE)ρBGEXPLOSS[;ESC])×((SIZEρBGFPPCT)*⍉(⌽SIZE)ρBGEXP[;ESC])×
      EXPENGMT
[48]  ESCEXPLOSS←ESCEXPLOSS×SIZEρ(AREABGESC⌊+⌿PAGEρESCEXPLOSS)÷+⌿PAGEρESCEXPLOSS
[49]  AREABGESC←AREABGESC-+⌿PAGEρESCEXPLOSS
[50]  BGESCLOSS←(ρENGAGE)ρ+/ESCEXPLOSS
[51]  BGESCLOST←+⌿BGESCLOSS
[52]  AREABGESCLOSS[AREA;]←AREABGESCLOSS[AREA;]+BGESCLOST
[53]  SUBBGESCLOSS←SUBBGESCLOSS+BGESCLOSS
[54]  BGESCATTRIT[DAY;]←BGESCATTRIT[DAY;]+BGESCLOST
[55]  CVEXPLOSS←(⍉(⌽SIZE)ρBGEXPLOSS[;CV])×((SIZEρBGFPPCT)*⍉(⌽SIZE)ρBGEXP[;CV])×EXP≥
ENGMT
[56]  CVEXPLOSS←CVEXPLOSS×SIZEρ(AREABGCV⌊+⌿PAGEρCVEXPLOSS)÷+⌿PAGEρCVEXPLOSS
[57]  AREABGCV←AREABGCV-+⌿PAGEρCVEXPLOSS
[58]  BGCVLOSS←(ρENGAGE)ρ+/CVEXPLOSS
[59]  BGCVLOST←+⌿BGCVLOSS
[60]  AREABGCVLOSS[AREA;]←AREABGCVLOSS[AREA;]+BGCVLOST
[61]  SUBBGCVLOSS←SUBBGCVLOSS+BGCVLOSS
[62]  BGCVATTRIT[DAY;]←BGCVATTRIT[DAY;]+BGCVLOST
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[63]  SUBTORPEXP←(⍉(⌽SIZE)⍴BGEXPLOSS[;TORP])×((SIZE⍴BGFPPCT)*⍉(⌽SIZE)⍴BGEXP[;TORP]≥
)×
      EXPENGMT
[64]  SUBTORPEXP←+/(⍴ENGAGE)⍴+/SUBTORPEXP
[65]  AREASUBTORP←AREASUBTORP-AREASUBTSK×⍉(⌽⍴AREASUBTSK)⍴SUBTORPEXP÷+/AREASUBTSK
[66]  EXCESSTORP←+/AREASUBTORP×AREASUBTORP<0
[67]  SUBEXCTORP←SUBEXCTORP+EXCESSTORP
[68]  AREASUBTORP←AREASUBTORP×AREASUBTORP>0
[69]  SUBSLCMEXP←(⍉(⌽SIZE)⍴BGEXPLOSS[;SLCM])×((SIZE⍴BGFPPCT)*⍉(⌽SIZE)⍴BGEXP[;SLCM]≥
)×
      EXPENGMT
[70]  SUBSLCMEXP←+/(⍴ENGAGE)⍴+/SUBSLCMEXP
[71]  AREASUBSLCM←AREASUBSLCM-AREASUBTSK×⍉(⌽⍴AREASUBTSK)⍴SUBSLCMEXP÷+/AREASUBTSK
[72]  EXCESSSLCM←+/AREASUBSLCM×AREASUBSLCM<0
[73]  SUBEXCSLCM←SUBEXCSLCM+EXCESSSLCM
[74]  AREASUBSLCM←AREASUBSLCM×AREASUBSLCM>0
[75]  SUBEXPLOSS←(⍉(⌽SIZE)⍴BGEXPLOSS[;SUB])×((SIZE⍴BGFPPCT)*⍉(⌽SIZE)⍴BGEXP[;SUB])×
      EXPENGMT
[76]  SUBEXPLOSS←(⍴ENGAGE)⍴+/SUBEXPLOSS
[77]  SUBLOSS←SUBEXPLOSS×⍉(⌽⍴SUBEXPLOSS)⍴((+/AREASUBTSK)⌊+/SUBEXPLOSS)÷+/SUBEXPLOSS
[78]  SUBSUNK←+/SUBLOSS
[79]  PCTSUBSUNK←⍉(⌽⍴AREASUBTSK)⍴SUBSUNK÷+/AREASUBTSK
[80]  AREASUBTORP←AREASUBTORP-PCTSUBSUNK×AREASUBTORP×AREASUBTSK>0
[81]  AREASUBSLCM←AREASUBSLCM-PCTSUBSUNK×AREASUBSLCM×AREASUBTSK>0
[82]  AREASUB←AREASUB-PCTSUBSUNK×AREASUBTSK
[83]  BGSUBATTRIT[DAY;]←BGSUBATTRIT[DAY;]+SUBSUNK
[84]  AREASUBLOSS[AREA;]←AREASUBLOSS[AREA;]+SUBSUNK
[85]  AREABGSUBLOSS[AREA;]←AREABGSUBLOSS[AREA;]+SUBSUNK
[86]  BGSUBLOSS←BGSUBLOSS+SUBLOSS
[87]  SUBATTRIT[DAY;]←SUBATTRIT[DAY;]+SUBSUNK
[88] OTHERATTRIT:OTHERBGVPLOST←AREABGVP×⍉(⌽⍴AREABGVP)⍴OTHERPKBGVP[;AREA]
[89]  AREABGVP←AREABGVP-OTHERBGVPLOST
[90]  BGVPQTY←BGVPQTY+AREABGVP
[91]  BGVPATTRIT[DAY;]←BGVPATTRIT[DAY;]++/OTHERBGVPLOST
[92]  OTHERBGSSNLOST←AREABGSSN×⍉(⌽⍴AREABGSSN)⍴OTHERPKBGSSN[;AREA]
[93]  AREABGSSN←AREABGSSN-OTHERBGSSNLOST
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[94]  BGSSNQTY←BGSSNQTY+AREABGSSN
[95]  BGSSNATTRIT[DAY;]←BGSSNATTRIT[DAY;]++/OTHERBGSSNLOST
[96]  OTHERBGESCLOST←AREABGESC×⍉(⌽⍴AREABGESC)⍴OTHERPKBGESC[;AREA]
[97]  AREABGESC←AREABGESC-OTHERBGESCLOST
[98]  BGESCQTY←BGESCQTY+AREABGESC
[99]  BGESCATTRIT[DAY;]←BGESCATTRIT[DAY;]++/OTHERBGESCLOST
[100] OTHERBGCVLOST←AREABGCV×⍉(⌽⍴AREABGCV)⍴OTHERPKBGCV[;AREA]
[101] AREABGCV←AREABGCV-OTHERBGCVLOST
[102] BGCVQTY←BGCVQTY+AREABGCV
[103] BGCVATTRIT[DAY;]←BGCVATTRIT[DAY;]++/OTHERBGCVLOST
    ∇
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    ∇CONVOY[⎕]∇
  ∇ CONVOY
[1]   AREACONMER←CONMERQTY×CONAREA=AREA
[2]   →0×⍳0=+/+/AREACONMER
[3]   CONMERQTY←CONMERQTY-AREACONMER
[4]   AREACONVP←CONVPQTY×AREACONMER>0
[5]   CONVPQTY←CONVPQTY-AREACONVP
[6]   AREACONSSN←CONSSNQTY×AREACONMER>0
[7]   CONSSNQTY←CONSSNQTY-AREACONSSN
[8]   AREACONESC←CONESCQTY×AREACONMER>0
[9]   CONESCQTY←CONESCQTY-AREACONESC
[10]  →OTHERATTRIT×⍳0=+/+/AREASUB
[11]  AREASUBTSK←AREASUB×⍉(⌽⍴AREASUB)⍴SUBTASKCON
[12]  AREASUBTSK←AREASUBTSK×(AREASUBTORP>0)∨AREASUBSLCM>0
[13]  VP←1
[14]  SSN←2
[15]  ESC←3
[16]  MER←4
[17]  CONFPINDEX←AREACONVP×⍉(⌽⍴AREACONVP)⍴CONFPSCORE[;VP]
[18]  CONFPINDEX←CONFPINDEX+AREACONSSN×⍉(⌽⍴AREACONSSN)⍴CONFPSCORE[;SSN]
[19]  CONFPINDEX←CONFPINDEX+AREACONESC×⍉(⌽⍴AREACONESC)⍴CONFPSCORE[;ESC]
[20]  CONFPINDEX←CONFPINDEX+AREACONMER×⍉(⌽⍴AREACONMER)⍴CONFPSCORE[;MER]
[21]  CONFPPCT←CONFPINDEX÷⍉(⌽⍴CONFPINDEX)⍴REFCONFPINDEX
[22]  ENGAGE←(⍉(⌽⍴SUBPENGCON[AREA;;])⍴+/AREASUBTSK)×SUBPENGCON[AREA;;]×(⍴SUBPENGCON[AR≥
EA;
      ;])⍴+/AREACONMER>0
[23]  ENGAGE←ENGAGE×⍉(⌽⍴ENGAGE)⍴((+/ENGAGE)⌊SUBCONENGLMT×+/AREASUBTSK)÷+/ENGAGE
[24]  ENGPERCON←ENGAGE÷(⍴ENGAGE)⍴+/AREACONMER>0
[25]  SIZE←((1↑⍴SUBAREA)×1↑⍴CONAREA),¯1↑⍴CONAREA
[26]  EXPENGMT←(⍉(⌽SIZE)⍴ENGPERCON)×SIZE⍴AREACONMER>0
[27]  TORP←5
[28]  SLCM←6
[29]  SUB←7
[30]  VPEXPLOSS←(⍉(⌽SIZE)⍴CONEXPLOSS[;VP])×((SIZE⍴CONFPPCT)*⍉(⌽SIZE)⍴CONEXP[;VP])×
      EXPENGMT
[31]  PAGE←(1↑⍴SUBAREA),⍴CONAREA
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[32]  VPEXPLOSS←VPEXPLOSS×SIZEρ(AREACONVP⌊+⌿PAGEρVPEXPLOSS)÷+⌿PAGEρVPEXPLOSS
[33]  AREACONVP←AREACONVP-+⌿PAGEρVPEXPLOSS
[34]  CONVPLOSS←(ρENGAGE)ρ+/VPEXPLOSS
[35]  CONVPLOST←+⌿CONVPLOSS
[36]  AREACONVPLOSS[AREA;]←AREACONVPLOSS[AREA;]+CONVPLOST
[37]  SUBCONVPLOSS←SUBCONVPLOSS+CONVPLOSS
[38]  CONVPATTRIT[DAY;]←CONVPATTRIT[DAY;]+CONVPLOST
[39]  SSNEXPLOSS←(⍉(⌽SIZE)ρCONEXPLOSS[;SSN])×((SIZEρCONFPPCT)*⍉(⌽SIZE)ρCONEXP[;SSN≥
])×
      EXPENGMT
[40]  SSNEXPLOSS←SSNEXPLOSS×SIZEρ(AREACONSSN⌊+⌿PAGEρSSNEXPLOSS)÷+⌿PAGEρSSNEXPLOSS
[41]  AREACONSSN←AREACONSSN-+⌿PAGEρSSNEXPLOSS
[42]  CONSSNLOSS←(ρENGAGE)ρ+/SSNEXPLOSS
[43]  CONSSNLOST←+⌿CONSSNLOSS
[44]  AREACONSSNLOSS[AREA;]←AREACONSSNLOSS[AREA;]+CONSSNLOST
[45]  SUBCONSSNLOSS←SUBCONSSNLOSS+CONSSNLOSS
[46]  CONSSNATTRIT[DAY;]←CONSSNATTRIT[DAY;]+CONSSNLOST
[47]  ESCEXPLOSS←(⍉(⌽SIZE)ρCONEXPLOSS[;ESC])×((SIZEρCONFPPCT)*⍉(⌽SIZE)ρCONEXP[;ESC≥
])×
      EXPENGMT
[48]  ESCEXPLOSS←ESCEXPLOSS×SIZEρ(AREACONESC⌊+⌿PAGEρESCEXPLOSS)÷+⌿PAGEρESCEXPLOSS
[49]  AREACONESC←AREACONESC-+⌿PAGEρESCEXPLOSS
[50]  CONESCLOSS←(ρENGAGE)ρ+/ESCEXPLOSS
[51]  CONESCLOST←+⌿CONESCLOSS
[52]  AREACONESCLOSS[AREA;]←AREACONESCLOSS[AREA;]+CONESCLOST
[53]  SUBCONESCLOSS←SUBCONESCLOSS+CONESCLOSS
[54]  CONESCATTRIT[DAY;]←CONESCATTRIT[DAY;]+CONESCLOST
[55]  MEREXPLOSS←(⍉(⌽SIZE)ρCONEXPLOSS[;MER])×((SIZEρCONFPPCT)*⍉(⌽SIZE)ρCONEXP[;MER≥
])×
      EXPENGMT
[56]  MEREXPLOSS←MEREXPLOSS×SIZEρ(AREACONMER⌊+⌿PAGEρMEREXPLOSS)÷+⌿PAGEρMEREXPLOSS
[57]  AREACONMER←AREACONMER-+⌿PAGEρMEREXPLOSS
[58]  CONMERLOSS←(ρENGAGE)ρ+/MEREXPLOSS
[59]  CONMERLOST←+⌿CONMERLOSS
[60]  AREACONMERLOSS[AREA;]←AREACONMERLOSS[AREA;]+CONMERLOST
[61]  SUBCONMERLOSS←SUBCONMERLOSS+CONMERLOSS
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[62]  CONMERATTRIT[DAY;]←CONMERATTRIT[DAY;]+CONMERLOST
[63]  SUBTORPEXP←(⍉(⌽SIZE)⍴CONEXPLOSS[;TORP])×((SIZE⍴CONFPPCT)*⍉(⌽SIZE)⍴CONEXP[;TO≥
RP])×
      EXPENGMT
[64]  SUBTORPEXP←+/(⍴ENGAGE)⍴+/SUBTORPEXP
[65]  AREASUBTORP←AREASUBTORP-AREASUBTSK×⍉(⌽⍴AREASUBTSK)⍴SUBTORPEXP÷+/AREASUBTSK
[66]  EXCESSTORP←+/AREASUBTORP×AREASUBTORP<0
[67]  SUBEXCTORP←SUBEXCTORP+EXCESSTORP
[68]  AREASUBTORP←AREASUBTORP×AREASUBTORP>0
[69]  SUBSLCMEXP←(⍉(⌽SIZE)⍴CONEXPLOSS[;SLCM])×((SIZE⍴CONFPPCT)*⍉(⌽SIZE)⍴CONEXP[;SL≥
CM])×
      EXPENGMT
[70]  SUBSLCMEXP←+/(⍴ENGAGE)⍴+/SUBSLCMEXP
[71]  AREASUBSLCM←AREASUBSLCM-AREASUBTSK×⍉(⌽⍴AREASUBTSK)⍴SUBSLCMEXP÷+/AREASUBTSK
[72]  EXCESSSLCM←+/AREASUBSLCM×AREASUBSLCM<0
[73]  SUBEXCSLCM←SUBEXCSLCM+EXCESSSLCM
[74]  AREASUBSLCM←AREASUBSLCM×AREASUBSLCM>0
[75]  SUBEXPLOSS←(⍉(⌽SIZE)⍴CONEXPLOSS[;SUB])×((SIZE⍴CONFPPCT)*⍉(⌽SIZE)⍴CONEXP[;SUB≥
])×
      EXPENGMT
[76]  SUBEXPLOSS←(⍴ENGAGE)⍴+/SUBEXPLOSS
[77]  SUBLOSS←SUBEXPLOSS×⍉(⌽⍴SUBEXPLOSS)⍴((+/AREASUBTSK)⌊+/SUBEXPLOSS)÷+/SUBEXPLOSS
[78]  SUBSUNK←+/SUBLOSS
[79]  PCTSUBSUNK←⍉(⌽⍴AREASUBTSK)⍴SUBSUNK÷+/AREASUBTSK
[80]  AREASUBTORP←AREASUBTORP-PCTSUBSUNK×AREASUBTORP×AREASUBTSK>0
[81]  AREASUBSLCM←AREASUBSLCM-PCTSUBSUNK×AREASUBSLCM×AREASUBTSK>0
[82]  AREASUB←AREASUB-PCTSUBSUNK×AREASUBTSK
[83]  CONSUBATTRIT[DAY;]←CONSUBATTRIT[DAY;]+SUBSUNK
[84]  AREASUBLOSS[AREA;]←AREASUBLOSS[AREA;]+SUBSUNK
[85]  AREACONSUBLOSS[AREA;]←AREACONSUBLOSS[AREA;]+SUBSUNK
[86]  CONSUBLOSS←CONSUBLOSS+SUBLOSS
[87]  SUBATTRIT[DAY;]←SUBATTRIT[DAY;]+SUBSUNK
[88] OTHERATTRIT:OTHERCONVPLOST←AREACONVP×⍉(⌽⍴AREACONVP)⍴OTHERPKCONVP[;AREA]
[89]  AREACONVP←AREACONVP-OTHERCONVPLOST
[90]  CONVPQTY←CONVPQTY+AREACONVP
[91]  CONVPATTRIT[DAY;]←CONVPATTRIT[DAY;]++/OTHERCONVPLOST
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[92]  OTHERCONSSNLOST←AREACONSSN×⍉(⌽⍴AREACONSSN)⍴OTHERPKCONSSN[;AREA]
[93]  AREACONSSN←AREACONSSN-OTHERCONSSNLOST
[94]  CONSSNQTY←CONSSNQTY+AREACONSSN
[95]  CONSSNATTRIT[DAY;]←CONSSNATTRIT[DAY;]++/OTHERCONSSNLOST
[96]  OTHERCONESCLOST←AREACONESC×⍉(⌽⍴AREACONESC)⍴OTHERPKCONESC[;AREA]
[97]  AREACONESC←AREACONESC-OTHERCONESCLOST
[98]  CONESCQTY←CONESCQTY+AREACONESC
[99]  CONESCATTRIT[DAY;]←CONESCATTRIT[DAY;]++/OTHERCONESCLOST
[100] OTHERCONMERLOST←AREACONMER×⍉(⌽⍴AREACONMER)⍴OTHERPKCONMER[;AREA]
[101] AREACONMER←AREACONMER-OTHERCONMERLOST
[102] CONMERQTY←CONMERQTY+AREACONMER
[103] CONMERATTRIT[DAY;]←CONMERATTRIT[DAY;]++/OTHERCONMERLOST
    ∇
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      ∇INDEPSHIP[⎕]∇
    ∇ INDEPSHIP
[1]   AREAIND←INDQTY×INDAREA=AREA
[2]   →0×⍳0=+/+/AREAIND
[3]   INDQTY←INDQTY-AREAIND
[4]   →OTHERATTRIT×⍳0=+/+/AREASUB
[5]   AREASUBTSK←(⍉(⌽⍴AREASUB)⍴SUBTASKIND)×AREASUB×AREASUBTORP>0
[6]   INDLOST←(+/AREAIND)×1-×⌿(1-SUBPDETIND[AREA;;]×SUBPKILLIND[AREA;;])*⍉(⌽⍴SUBPKIL≥
LIND[
      AREA;;])⍴+/AREASUBTSK
[7]   SUBPK←1-(1-SUBPDETIND[AREA;;]×SUBPKILLIND[AREA;;])*⍉(⌽⍴SUBPKILLIND[AREA;;])⍴+/
      AREASUBTSK
[8]   INDLOSS←((⍴SUBPK)⍴INDLOST)×SUBPK÷(⍴SUBPK)⍴+⌿SUBPK
[9]   ENGAGE←INDLOSS×1÷SUBPKILLIND[AREA;;]
[10]  ENGAGE←ENGAGE×⍉(⌽⍴ENGAGE)⍴((+/ENGAGE)⌊SUBINDENGLMT×+/AREASUBTSK)÷+/ENGAGE
[11]  INDLOSS←ENGAGE×SUBPKILLIND[AREA;;]
[12]  INDLOST←+⌿INDLOSS
[13]  SUBSUNK←(+/AREASUBTSK)×1-×/(1-INDPKILLSUB[AREA;;])*ENGAGE÷⍉(⌽⍴ENGAGE)⍴+/AREASUBT≥
SK
[14]  INDPK←1-(1-INDPKILLSUB[AREA;;])*ENGAGE÷⍉(⌽⍴ENGAGE)⍴+/AREASUBTSK
[15]  SUBLOSS←(⍉(⌽⍴INDPK)⍴SUBSUNK)×INDPK÷⍉(⌽⍴INDPK)⍴+/INDPK
[16]  AREAIND←AREAIND×⍉(⌽⍴AREAIND)⍴1-INDLOST÷+/AREAIND
[17]  INDATTRIT[DAY;]←INDATTRIT[DAY;]+INDLOST
[18]  AREAINDLOSS[AREA;]←AREAINDLOSS[AREA;]+INDLOST
[19]  SUBINDLOSS←SUBINDLOSS+INDLOSS
[20]  SUBTORPEXP←+/SUBTORPPERIND×ENGAGE
[21]  AREASUBTORP←AREASUBTORP-AREASUBTSK×⍉(⌽⍴AREASUBTSK)⍴SUBTORPEXP÷+/AREASUBTSK
[22]  EXCESSTORP←+/AREASUBTORP×AREASUBTORP<0
[23]  SUBEXCTORP←SUBEXCTORP+EXCESSTORP
[24]  AREASUBTORP←AREASUBTORP×AREASUBTORP>0
[25]  PCTSUBSUNK←⍉(⌽⍴AREASUBTSK)⍴SUBSUNK÷+/AREASUBTSK
[26]  AREASUBTORP←AREASUBTORP-PCTSUBSUNK×AREASUBTORP×AREASUBTSK>0
[27]  AREASUBSLCM←AREASUBSLCM-PCTSUBSUNK×AREASUBSLCM×AREASUBTSK>0
[28]  AREASUB←AREASUB-PCTSUBSUNK×AREASUBTSK
[29]  FLGDAT←(+/ENGAGE)-SUBSUNK
[30]  SUBATTRIT[DAY;]←SUBATTRIT[DAY;]+SUBSUNK
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[31]  INDSUBATTRIT[DAY;]←INDSUBATTRIT[DAY;]+SUBSUNK
[32]  AREASUBLOSS[AREA;]←AREASUBLOSS[AREA;]+SUBSUNK
[33]  AREAINDSUBLOSS[AREA;]←AREAINDSUBLOSS[AREA;]+SUBSUNK
[34]  INDSUBLOSS←INDSUBLOSS+SUBLOSS
[35] OTHERATTRIT:OTHERINDLOST←AREAIND×⍉(⌽⍴AREAIND)⍴OTHERPKIND[;AREA]
[36]  AREAIND←AREAIND-OTHERINDLOST
[37]  INDQTY←INDQTY+AREAIND
[38]  INDATTRIT[DAY;]←INDATTRIT[DAY;]++/OTHERINDLOST
    ∇
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     ∇MINES[⎕]∇
   ∇ MINES
[1]    →0×⍳DAY<MINESKED[AREA]
[2]    →OTHERATTRIT×⍳0=+/+/AREASUB
[3]    SUBSUNK←(+/AREASUB)×1-×/(1-MINEPDET[AREA;;]×MINEPKILL[AREA;;])*(⍴MINEPKILL[AREA;;])
       ⍴MINEQTY[;AREA]
[4]    MPK←1-(1-MINEPDET[AREA;;]×MINEPKILL[AREA;;])*(⍴MINEPKILL[AREA;;])⍴MINEQTY[;AREA]
[5]    SUBLOSS←(⍉(⌽⍴MPK)⍴SUBSUNK)×MPK÷⍉(⌽⍴MPK)⍴+/MPK
[6]    PCTSUBSURV←⍉(⌽⍴AREASUB)⍴1-SUBSUNK÷+/AREASUB
[7]    AREASUBTORP←AREASUBTORP×PCTSUBSURV
[8]    AREASUBSLCM←AREASUBSLCM×PCTSUBSURV
[9]    AREASUB←AREASUB×PCTSUBSURV
[10]   SUBATTRIT[DAY;]←SUBATTRIT[DAY;]+SUBSUNK
[11]   MINESUBATTRIT[DAY;]←MINESUBATTRIT[DAY;]+SUBSUNK
[12]   AREASUBLOSS[AREA;]←AREASUBLOSS[AREA;]+SUBSUNK
[13]   AREAMINESUBLOSS[AREA;]←AREAMINESUBLOSS[AREA;]+SUBSUNK
[14]   MINESUBLOSS←MINESUBLOSS+SUBLOSS
[15]   MINEQTY[;AREA]←MINEQTY[;AREA]-+⌿SUBLOSS×1÷MINEPKILL[AREA;;]
[16] OTHERATTRIT:MINEQTY[;AREA]←MINEQTY[;AREA]×1-OTHERPKMINE[;AREA]
   ∇
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     ∇PATROLAIRCRAFT[⎕]∇
   ∇ PATROLAIRCRAFT
[1]    AREAVP←VPQTY[;AREA]
[2]    →RETURN×⍳0=+/AREAVP
[3]    SOSPDET←SOSUSPDETSUB[;AREA]×SOSUSSKED[AREA]>DAY
[4]    →OARPROS×⍳0=+/+/AREASUB
[5]    FLGDAT←FLGDAT⌊+/AREASUB
[6]    PFLGDAT←(+/AREASUB)⌊FLGDAT÷+/AREASUB
[7]    PDATUM←SOSPDET+PFLGDAT-SOSPDET×PFLGDAT
[8]    DATUMS←PDATUM×+/AREASUB
[9]    →NODATUMS×⍳0=+/DATUMS
[10]   SUBSUNK←DATUMS×1-×/(1-VPPDETDAT[AREA;;]×VPPKILLSUB[AREA;;])*(⍴VPPKILLSUB[AREA;;])⍴
       AREAVP
[11]   VPPK←1-(1-VPPDETDAT[AREA;;]×VPPKILLSUB[AREA;;])*(⍴VPPKILLSUB[AREA;;])⍴AREAVP
[12] ATTRITION:SUBLOSS←(⍉(⌽⍴VPPK)⍴SUBSUNK)×VPPK÷⍉(⌽⍴VPPK)⍴+/VPPK
[13]   ENGAGE←SUBLOSS×1÷VPPKILLSUB[AREA;;]
[14]   ENGAGE←ENGAGE×⍉(⌽⍴ENGAGE)⍴((+⌿ENGAGE)⌊VPSUBENGLMT×AREAVP)÷+⌿ENGAGE
[15]   SUBLOSS←ENGAGE×VPPKILLSUB[AREA;;]
[16]   SUBSUNK←+/SUBLOSS
[17]   VPLOST←AREAVP×1-×⌿(1-SUBPKILLVP[AREA;;])*ENGAGE÷(⍴ENGAGE)⍴AREAVP
[18]   SPK←1-(1-SUBPKILLVP[AREA;;])*ENGAGE÷(⍴ENGAGE)⍴AREAVP
[19]   VPLOSS←((⍴SPK)⍴VPLOST)×SPK÷(⍴SPK)⍴+⌿SPK
[20]   PCTSUBSURV←⍉(⌽⍴AREASUB)⍴1-SUBSUNK÷+/AREASUB
[21]   AREASUBTORP←AREASUBTORP×PCTSUBSURV
[22]   AREASUBSLCM←AREASUBSLCM×PCTSUBSURV
[23]   AREASUB←AREASUB×PCTSUBSURV
[24]   SUBATTRIT[DAY;]←SUBATTRIT[DAY;]+SUBSUNK
[25]   VPSUBATTRIT[DAY;]←VPSUBATTRIT[DAY;]+SUBSUNK
[26]   AREASUBLOSS[AREA;]←AREASUBLOSS[AREA;]+SUBSUNK
[27]   AREAVPSUBLOSS[AREA;]←AREAVPSUBLOSS[AREA;]+SUBSUNK
[28]   VPSUBLOSS←VPSUBLOSS+SUBLOSS
[29]   AREAVP←AREAVP-VPLOST
[30]   VPATTRIT[DAY;]←VPATTRIT[DAY;]+VPLOST
[31]   AREAVPLOSS[AREA;]←AREAVPLOSS[AREA;]+VPLOST
[32]   SUBVPLOSS←SUBVPLOSS+VPLOSS
[33]   →OTHERATTRIT
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[34] NODATUMS:SUBSUNK←(+/AREASUB)×1-×/(1-VPPDETSUB[AREA;;]×VPPKILLSUB[AREA;;])*(ρ
      VPPKILLSUB[AREA;;])ρAREAVP
[35]  VPPK←1-(1-VPPDETSUB[AREA;;]×VPPKILLSUB[AREA;;])*(ρVPPKILLSUB[AREA;;])ρAREAVP
[36]  →ATTRITION
[37] OARPROS:→OTHERATTRIT×⍳0=+/+/AREASUBOAR
[38]  DATUMS←SOSPDET×+/AREASUBOAR
[39]  →NOOARDATUMS×⍳0=+/DATUMS
[40]  SUBSUNK←DATUMS×1-×/(1-VPPDETDAT[AREA;;]×VPPKILLSUB[AREA;;])*(ρVPPKILLSUB[AREA;;])ρ
      AREAVP
[41]  VPPK←1-(1-VPPDETDAT[AREA;;]×VPPKILLSUB[AREA;;])*(ρVPPKILLSUB[AREA;;])ρAREAVP
[42] OARATTRITION:SUBLOSS←(⍉(⌽ρVPPK)ρSUBSUNK)×VPPK÷⍉(⌽ρVPPK)ρ+/VPPK
[43]  ENGAGE←SUBLOSS×1÷VPPKILLSUB[AREA;;]
[44]  ENGAGE←ENGAGE×⍉(⌽ρENGAGE)ρ((+⌿ENGAGE)⌊VPSUBENGLMT×AREAVP)÷+⌿ENGAGE
[45]  SUBLOSS←ENGAGE×VPPKILLSUB[AREA;;]
[46]  SUBSUNK←+/SUBLOSS
[47]  VPLOST←AREAVP×1-×⌿(1-SUBPKILLVP[AREA;;])*ENGAGE÷(ρENGAGE)ρAREAVP
[48]  SPK←1-(1-SUBPKILLVP[AREA;;])*ENGAGE÷(ρENGAGE)ρAREAVP
[49]  VPLOSS←((ρSPK)ρVPLOST)×SPK÷(ρSPK)ρ+⌿SPK
[50]  PCTSUBSURV←⍉(⌽ρAREASUBOAR)ρ1-SUBSUNK÷+/AREASUBOAR
[51]  AREASUBOAR←AREASUBOAR×PCTSUBSURV
[52]  SUBATTRIT[DAY;]←SUBATTRIT[DAY;]+SUBSUNK
[53]  VPSUBATTRIT[DAY;]←VPSUBATTRIT[DAY;]+SUBSUNK
[54]  AREASUBLOSS[AREA;]←AREASUBLOSS[AREA;]+SUBSUNK
[55]  AREAVPSUBLOSS[AREA;]←AREAVPSUBLOSS[AREA;]+SUBSUNK
[56]  VPSUBLOSS←VPSUBLOSS+SUBLOSS
[57]  VPQTY[;AREA]←AREAVP-VPLOST
[58]  VPATTRIT[DAY;]←VPATTRIT[DAY;]+VPLOST
[59]  AREAVPLOSS[AREA;]←AREAVPLOSS[AREA;]+VPLOST
[60]  SUBVPLOSS←SUBVPLOSS+VPLOSS
[61] OTHERATTRIT:OTHERVPLOST←AREAVP×OTHERPKVP[;AREA]
[62]  AREAVP←AREAVP-OTHERVPLOST
[63]  VPQTY[;AREA]←AREAVP
[64]  VPATTRIT[DAY;]←VPATTRIT[DAY;]+OTHERVPLOST
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[65]  →RETURN
[66] NOOARDATUMS:SUBSUNK←(+/AREASUB)×1-×/(1-VPPDETSUB[AREA;;]×VPPKILLSUB[AREA;;])*(ρ
      VPPKILLSUB[AREA;;])ρAREAVP
[67]  VPPK←1-(1-VPPDETSUB[AREA;;]×VPPKILLSUB[ARREA;;])*(ρVPPKILLSUB[AREA;;])ρAREAVP
[68]  →OARATTRITION
[69] RETURN:FLGDAT←(1↑ρSUBQTY)ρ0
    ∇
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```
    ∇RETYPESUBMARINES[⎕]∇
  ∇ RETYPESUBMARINES
[1]  RETYPESUB:RESUB←SUBQTY×SUBQTY<⍉(⌽⍴SUBQTY)⍴SUBBKPT
[2]   →RETYPESSN×⍳0=+/+/RESUB
[3]   RESUBTORP←SUBTORP×RESUB>0
[4]   RESUBSLCM←SUBSLCM×RESUB>0
[5]   SUBQTY←SUBQTY-RESUB
[6]   SUBTORP←SUBTORP-RESUBTORP
[7]   SUBSLCM←SUBSLCM-RESUBSLCM
[8]   SUBQTY←SUBQTY+RESUB[SUBRETYPE;]
[9]   SUBTORP←SUBTORP+RESUBTORP[SUBRETYPE;]
[10]  SUBSLCM←SUBSLCM+RESUBSLCM[SUBRETYPE;]
[11]  →RETYPESUB
[12] RETYPESSN:RESSN←SSNQTY×SSNQTY<⍉(⌽⍴SSNQTY)⍴SSNBKPT
[13]  →0×⍳0=+/+/RESSN
[14]  RESSNTORP←SSNTORP×RESSN>0
[15]  RESSNTLAM←SSNTLAM×RESSN>0
[16]  RESSNTASM←SSNTASM×RESSN>0
[17]  SSNQTY←SSNQTY-RESSN
[18]  SSNTORP←SSNTORP-RESSNTORP
[19]  SSNTLAM←SSNTLAM-RESSNTLAM
[20]  SSNTASM←SSNTASM-RESSNTASM
[21]  SSNQTY←SSNQTY+RESSN[SSNRETYPE;]
[22]  SSNTORP←SSNTORP+RESSNTORP[SSNRETYPE;]
[23]  SSNTLAM←SSNTLAM+RESSNTLAM[SSNRETYPE;]
[24]  SSNTASM←SSNTASM+RESSNTASM[SSNRETYPE;]
[25]  →RETYPESSN
  ∇
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      ∇UNREPGROUP[⎕]∇
    ∇ UNREPGROUP
[1]   AREAURGAUX←URGAUXQTY×URGAREA=AREA
[2]   →0×⍳0=+/+/AREAURGAUX
[3]   URGAUXQTY←URGAUXQTY-AREAURGAUX
[4]   AREAURGVP←URGVPQTY×AREAURGAUX>0
[5]   URGVPQTY←URGVPQTY-AREAURGVP
[6]   AREAURGSSN←URGSSNQTY×AREAURGAUX>0
[7]   URGSSNQTY←URGSSNQTY-AREAURGSSN
[8]   AREAURGESC←URGESCQTY×AREAURGAUX>0
[9]   URGESCQTY←URGESCQTY-AREAURGESC
[10]  →OTHERATTRIT×⍳0=+/+/AREASUB
[11]  AREASUBTSK←AREASUB×⍉(⌽⍴AREASUB)⍴SUBTASKURG
[12]  AREASUBTSK←AREASUBTSK×(AREASUBTORP>0)∨AREASUBSLCM>0
[13]  VP←1
[14]  SSN←2
[15]  ESC←3
[16]  AUX←4
[17]  URGFPINDEX←AREAURGVP×⍉(⌽⍴AREAURGVP)⍴URGFPSCORE[;VP]
[18]  URGFPINDEX←URGFPINDEX+AREAURGSSN×⍉(⌽⍴AREAURGSSN)⍴URGFPSCORE[;SSN]
[19]  URGFPINDEX←URGFPINDEX+AREAURGESC×⍉(⌽⍴AREAURGESC)⍴URGFPSCORE[;ESC]
[20]  URGFPINDEX←URGFPINDEX+AREAURGAUX×⍉(⌽⍴AREAURGAUX)⍴URGFPSCORE[;AUX]
[21]  URGFPPCT←URGFPINDEX÷⍉(⌽⍴URGFPINDEX)⍴REFURGFPINDEX
[22]  ENGAGE←(⍉(⌽⍴SUBPENGURG[AREA;;])⍴+/AREASUBTSK)×SUBPENGURG[AREA;;]×(⍴SUBPENGURG[AR≥
EA;
      ;])⍴+/AREAURGAUX>0
[23]  ENGAGE←ENGAGE×⍉(⌽⍴ENGAGE)⍴((+/ENGAGE)⌊SUBURGENGLMT×+/AREASUBTSK)÷+/ENGAGE
[24]  ENGPERURG←ENGAGE÷(⍴ENGAGE)⍴+/AREAURGAUX>0
[25]  SIZE←((1↑⍴SUBAREA)×1↑⍴URGAREA),¯1↑⍴URGAREA
[26]  EXPENGMT←(⍉(⌽SIZE)⍴ENGPERURG)×SIZE⍴AREAURGAUX>0
[27]  TORP←5
[28]  SLCM←6
[29]  SUB←7
[30]  VPEXPLOSS←(⍉(⌽SIZE)⍴URGEXPLOSS[;VP])×((SIZE⍴URGFPPCT)*⍉(⌽SIZE)⍴URGEXP[;VP])×
      EXPENGMT
[31]  PAGE←(1↑⍴SUBAREA),⍴URGAREA
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[32]  VPEXPLOSS←VPEXPLOSS×SIZEρ(AREAURGVP⌊+⌿PAGEρVPEXPLOSS)÷+⌿PAGEρVPEXPLOSS
[33]  AREAURGVP←AREAURGVP-+⌿PAGEρVPEXPLOSS
[34]  URGVPLOSS←(ρENGAGE)ρ+/VPEXPLOSS
[35]  URGVPLOST←+⌿URGVPLOSS
[36]  AREAURGVPLOSS[AREA;]←AREAURGVPLOSS[AREA;]+URGVPLOST
[37]  SUBURGVPLOSS←SUBURGVPLOSS+URGVPLOSS
[38]  URGVPATTRIT[DAY;]←URGVPATTRIT[DAY;]+URGVPLOST
[39]  SSNEXPLOSS←(⍉(⌽SIZE)ρURGEXPLOSS[;SSN])×((SIZEρURGFPPCT)⋆⍉(⌽SIZE)ρURGEXP[;SSN≥
])×
      EXPENGMT
[40]  SSNEXPLOSS←SSNEXPLOSS×SIZEρ(AREAURGSSN⌊+⌿PAGEρSSNEXPLOSS)÷+⌿PAGEρSSNEXPLOSS
[41]  AREAURGSSN←AREAURGSSN-+⌿PAGEρSSNEXPLOSS
[42]  URGSSNLOSS←(ρENGAGE)ρ+/SSNEXPLOSS
[43]  URGSSNLOST←+⌿URGSSNLOSS
[44]  AREAURGSSNLOSS[AREA;]←AREAURGSSNLOSS[AREA;]+URGSSNLOST
[45]  SUBURGSSNLOSS←SUBURGSSNLOSS+URGSSNLOSS
[46]  URGSSNATTRIT[DAY;]←URGSSNATTRIT[DAY;]+URGSSNLOST
[47]  ESCEXPLOSS←(⍉(⌽SIZE)ρURGEXPLOSS[;ESC])×((SIZEρURGFPPCT)⋆⍉(⌽SIZE)ρURGEXP[;ESC≥
])×
      EXPENGMT
[48]  ESCEXPLOSS←ESCEXPLOSS×SIZEρ(AREAURGESC⌊+⌿PAGEρESCEXPLOSS)÷+⌿PAGEρESCEXPLOSS
[49]  AREAURGESC←AREAURGESC-+⌿PAGEρESCEXPLOSS
[50]  URGESCLOSS←(ρENGAGE)ρ+/ESCEXPLOSS
[51]  URGESCLOST←+⌿URGESCLOSS
[52]  AREAURGESCLOSS[AREA;]←AREAURGESCLOSS[AREA;]+URGESCLOST
[53]  SUBURGESCLOSS←SUBURGESCLOSS+URGESCLOSS
[54]  URGESCATTRIT[DAY;]←URGESCATTRIT[DAY;]+URGESCLOST
[55]  AUXEXPLOSS←(⍉(⌽SIZE)ρURGEXPLOSS[;AUX])×((SIZEρURGFPPCT)⋆⍉(⌽SIZE)ρURGEXP[;AUX≥
])×
      EXPENGMT
[56]  AUXEXPLOSS←AUXEXPLOSS×SIZEρ(AREAURGAUX⌊+⌿PAGEρAUXEXPLOSS)÷+⌿PAGEρAUXEXPLOSS
[57]  AREAURGAUX←AREAURGAUX-+⌿PAGEρAUXEXPLOSS
[58]  URGAUXLOSS←(ρENGAGE)ρ+/AUXEXPLOSS
[59]  URGAUXLOST←+⌿URGAUXLOSS
[60]  AREAURGAUXLOSS[AREA;]←AREAURGAUXLOSS[AREA;]+URGAUXLOST
[61]  SUBURGAUXLOSS←SUBURGAUXLOSS+URGAUXLOSS
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[62]   URGAUXATTRIT[DAY;]←URGAUXATTRIT[DAY;]+URGAUXLOST
[63]   SUBTORPEXP←(⍉(⌽SIZE)⍴URGEXPLOSS[;TORP])×((SIZE⍴URGFPPCT)*⍉(⌽SIZE)⍴URGEXP[;TO≥
RP])×
       EXPENGMT
[64]   SUBTORPEXP←+/(⍴ENGAGE)⍴+/SUBTORPEXP
[65]   AREASUBTORP←AREASUBTORP-AREASUBTSK×⍉(⌽⍴AREASUBTSK)⍴SUBTORPEXP÷+/AREASUBTSK
[66]   EXCESSTORP←+/AREASUBTORP×AREASUBTORP<0
[67]   SUBEXCTORP←SUBEXCTORP+EXCESSTORP
[68]   AREASUBTORP←AREASUBTORP×AREASUBTORP>0
[69]   SUBSLCMEXP←(⍉(⌽SIZE)⍴URGEXPLOSS[;SLCM])×((SIZE⍴URGFPPCT)*⍉(⌽SIZE)⍴URGEXP[;SL≥
CM])×
       EXPENGMT
[70]   SUBSLCMEXP←+/(⍴ENGAGE)⍴+/SUBSLCMEXP
[71]   AREASUBSLCM←AREASUBSLCM-AREASUBTSK×⍉(⌽⍴AREASUBTSK)⍴SUBSLCMEXP÷+/AREASUBTSK
[72]   EXCESSSLCM←+/AREASUBSLCM×AREASUBSLCM<0
[73]   SUBEXCSLCM←SUBEXCSLCM+EXCESSSLCM
[74]   AREASUBSLCM←AREASUBSLCM×AREASUBSLCM>0
[75]   SUBEXPLOSS←(⍉(⌽SIZE)⍴URGEXPLOSS[;SUB])×((SIZE⍴URGFPPCT)*⍉(⌽SIZE)⍴URGEXP[;SUB≥
])×
       EXPENGMT
[76]   SUBEXPLOSS←(⍴ENGAGE)⍴+/SUBEXPLOSS
[77]   SUBLOSS←SUBEXPLOSS×⍉(⌽⍴SUBEXPLOSS)⍴((+/AREASUBTSK)⌊+/SUBEXPLOSS)÷+/SUBEXPLOSS
[78]   SUBSUNK←+/SUBLOSS
[79]   PCTSUBSUNK←⍉(⌽⍴AREASUBTSK)⍴SUBSUNK÷+/AREASUBTSK
[80]   AREASUBTORP←AREASUBTORP-PCTSUBSUNK×AREASUBTORP×AREASUBTSK>0
[81]   AREASUBSLCM←AREASUBSLCM-PCTSUBSUNK×AREASUBSLCM×AREASUBTSK>0
[82]   AREASUB←AREASUB-PCTSUBSUNK×AREASUBTSK
[83]   URGSUBATTRIT[DAY;]←URGSUBATTRIT[DAY;]+SUBSUNK
[84]   AREASUBLOSS[AREA;]←AREASUBLOSS[AREA;]+SUBSUNK
[85]   AREAURGSUBLOSS[AREA;]←AREAURGSUBLOSS[AREA;]+SUBSUNK
[86]   URGSUBLOSS←URGSUBLOSS+SUBLOSS
[87]   SUBATTRIT[DAY;]←SUBATTRIT[DAY;]+SUBSUNK
[88] OTHERATTRIT:OTHERURGVPLOST←AREAURGVP×⍉(⌽⍴AREAURGVP)⍴OTHERPKURGVP[;AREA]
[89]   AREAURGVP←AREAURGVP-OTHERURGVPLOST
[90]   URGVPQTY←URGVPQTY+AREAURGVP
[91]   URGVPATTRIT[DAY;]←URGVPATTRIT[DAY;]++/OTHERURGVPLOST
```

```
[92]  OTHERURGSSNLOST←AREAURGSSN×⍉(⌽⍴AREAURGSSN)⍴OTHERPKURGSSN[;AREA]
[93]  AREAURGSSN←AREAURGSSN-OTHERURGSSNLOST
[94]  URGSSNQTY←URGSSNQTY+AREAURGSSN
[95]  URGSSNATTRIT[DAY;]←URGSSNATTRIT[DAY;]++/OTHERURGSSNLOST
[96]  OTHERURGESCLOST←AREAURGESC×⍉(⌽⍴AREAURGESC)⍴OTHERPKURGESC[;AREA]
[97]  AREAURGESC←AREAURGESC-OTHERURGESCLOST
[98]  URGESCQTY←URGESCQTY+AREAURGESC
[99]  URGESCATTRIT[DAY;]←URGESCATTRIT[DAY;]++/OTHERURGESCLOST
[100] OTHERURGAUXLOST←AREAURGAUX×⍉(⌽⍴AREAURGAUX)⍴OTHERPKURGAUX[;AREA]
[101] AREAURGAUX←AREAURGAUX-OTHERURGAUXLOST
[102] URGAUXQTY←URGAUXQTY+AREAURGAUX
[103] URGAUXATTRIT[DAY;]←URGAUXATTRIT[DAY;]++/OTHERURGAUXLOST
    ∇
```

```
      ∇INITIALIZE[⎕]∇
    ∇ INITIALIZE;A;B;BL;C;CL;D;I;IL;M;N;NL;NOL;S;SL;SOL;U;UL;V
[1]   ⍝   INITIALIZE FUNCTION MAY BE USED TO SHAPE INPUT VARIABLES
[2]   ⍝   TO APPROPRIATE SIZE FOR CAMPAIGN. ALL VARIABLES (EXCEPT:
[3]   ⍝   AREAQTY,DURATION ) ARE INITIALIZED TO ZERO.
[4]   ⍝   FUNCTION IS EXECUTED BY TYPING 'INITIALIZE';
[5]   ⍝   THE USER IS THEN REQUESTED TO INPUT VARIOUS SCALAR
[6]   ⍝   QUANTITIES AS NECESSARY TO SHAPE ALL INPUT VARIABLES.
[7]   'ENTER NUMBER OF AREAS:'
[8]   AREAQTY←A←⎕
[9]   'ENTER DURATION IN DAYS OF CAMPAIGN:'
[10]  DURATION←D←⎕
[11]  'ENTER NUMBER OF HOSTILE SUBMARINE TYPES:'
[12]  S←⎕
[13]  'ENTER MAXIMUM LENGTH IN DAYS OF ANY HOSTILE SUBMARINE CYCLE:'
[14]  SL←⎕
[15]  'ENTER MAXIMUM LENGTH IN DAYS OF ANY HOSTILE SUBMARINE OOA REPLENISHMENT CYCLE:'
[16]  SOL←⎕
[17]  'ENTER NUMBER OF ATTACK SUBMARINE TYPES:'
[18]  N←⎕
[19]  'ENTER MAXIMUM LENGTH IN DAYS OF ANY ATTACK SUBMARINE CYCLE:'
[20]  NL←⎕
[21]  'ENTER MAXIMUM LENGTH IN DAYS OF ANY ATTACK SUBMARINE OOA REPLENISHMENT CYCLE:'
[22]  NOL←⎕
[23]  'ENTER NUMBER OF MINE TYPES:'
[24]  M←⎕
[25]  'ENTER NUMBER OF VP TYPES:'
[26]  V←⎕
[27]  'ENTER NUMBER OF INDEPENDENT SHIPPING TYPES:'
[28]  I←⎕
[29]  'ENTER MAXIMUM LENGTH IN DAYS OF ANY INDEPENDENT SHIPPING CYCLE:'
[30]  IL←⎕
[31]  'ENTER NUMBER OF CONVOY TYPES:'
[32]  C←⎕
[33]  'ENTER MAXIMUM LENGTH IN DAYS OF ANY CONVOY CYCLE:'
[34]  CL←⎕
```

```
[35]  'ENTER NUMBER OF UNDERWAY REPLENISHMENT GROUP TYPES:'
[36]  U←⎕
[37]  'ENTER MAXIMUM LENGTH IN DAYS OF ANY URG CYCLE:'
[38]  UL←⎕
[39]  'ENTER NUMBER OF BATTLE GROUP TYPES:'
[40]  B←⎕
[41]  'ENTER MAXIMUM LENGTH IN DAYS OF ANY BG CYCLE:'
[42]  BL←⎕
[43]  SUBAREA←(S,SL)ρ0
[44]  SUBBGENGLMT←Sρ0
[45]  SUBBKPT←Sρ0
[46]  SUBCONENGLMT←Sρ0
[47]  SUBEND←Sρ0
[48]  SUBINDENGLMT←Sρ0
[49]  SUBOARAREA←(S,SOL)ρ0
[50]  SUBOAREND←Sρ0
[51]  SUBOARQTY←(S,SOL)ρ0
[52]  SUBOFF←Sρ0
[53]  SUBON←Sρ0
[54]  SUBPCTOAR←Sρ0
[55]  SUBPDETIND←(A,S,I)ρ0
[56]  SUBPENGBG←(A,S,B)ρ0
[57]  SUBPENGCON←(A,S,C)ρ0
[58]  SUBPENGURG←(A,S,U)ρ0
[59]  SUBPKILLIND←(A,S,I)ρ0
[60]  SUBPKILLSSN←(A,S,N)ρ0
[61]  SUBPKILLVP←(A,S,V)ρ0
[62]  SUBQTY←(S,SL)ρ0
[63]  SUBRETYPE←Sρ0
[64]  SUBSKED←(S,D)ρ0
[65]  SUBSLCMLOAD←Sρ0
[66]  SUBTASKBG←Sρ0
[67]  SUBTASKCON←Sρ0
[68]  SUBTASKIND←Sρ0
[69]  SUBTASKURG←Sρ0
[70]  SUBTORPLOAD←Sρ0
```

```
[71]  SUBTORPPERIND←(S,I)ρ0
[72]  SUBTORPPERSSN←(S,N)ρ0
[73]  SUBURGENGLMT←Sρ0
[74]  ZEROSUBSLCM←Sρ0
[75]  ZEROSUBTORP←Sρ0
[76]  SSNAREA←(N,NL)ρ0
[77]  SSNBKPT←Nρ0
[78]  SSNEND←Nρ0
[79]  SSNOARAREA←(N,NOL)ρ0
[80]  SSNOAREND←Nρ0
[81]  SSNOARQTY←(N,NOL)ρ0
[82]  SSNOFF←Nρ0
[83]  SSNON←Nρ0
[84]  SSNPCTOAR←Nρ0
[85]  SSNPDETSUB←(A,S,N)ρ0
[86]  SSNPKILLSUB←(A,S,N)ρ0
[87]  SSNQTY←(N,NL)ρ0
[88]  SSNRETYPE←Nρ0
[89]  SSNSKED←(N,D)ρ0
[90]  SSNSUBENGLMT←Nρ0
[91]  SSNTASMLOAD←Nρ0
[92]  SSNTLAMLOAD←Nρ0
[93]  SSNTORPLOAD←Nρ0
[94]  SSNTORPPERSUB←(S,N)ρ0
[95]  OTHERPKSSN←(N,A)ρ0
[96]  ZEROSSNTASM←Nρ0
[97]  ZEROSSNTLAM←Nρ0
[98]  ZEROSSNTORP←Nρ0
[99]  MINEPDET←(A,S,M)ρ0
[100] MINEPKILL←(A,S,M)ρ0
[101] MINEQTY←(M,A)ρ0
[102] MINESKED←Aρ0
[103] OTHERPKMINE←(M,A)ρ0
[104] VPPDETDAT←(A,S,V)ρ0
[105] VPPDETSUB←(A,S,V)ρ0
[106] VPPKILLSUB←(A,S,V)ρ0
```

```
[107] VPQTY←(V,A)ρ0
[108] VPSUBENGLMT←Vρ0
[109] OTHERPKVP←(V,A)ρ0
[110] SOSUSPDETSUB←(S,A)ρ0
[111] SOSUSSKED←Aρ0
[112] INDAREA←(I,IL)ρ0
[113] INDEND←Iρ0
[114] INDPKILLSUB←(A,S,I)ρ0
[115] INDQTY←(I,IL)ρ0
[116] INDSKED←(I,D)ρ0
[117] OTHERPKIND←(I,A)ρ0
[118] CONAREA←(C,CL)ρ0
[119] CONEND←Cρ0
[120] CONESCQTY←(C,CL)ρ0
[121] CONEXP←((C×S),7)ρ0
[122] CONEXPLOSS←((C×S),7)ρ0
[123] CONFPSCORE←(C,4)ρ0
[124] CONMERQTY←(C,CL)ρ0
[125] CONSCREEN←(C,3)ρ0
[126] CONSKED←(C,D)ρ0
[127] CONSSNQTY←(C,CL)ρ0
[128] CONVPQTY←(C,CL)ρ0
[129] OTHERPKCONESC←(C,A)ρ0
[130] OTHERPKCONMER←(C,A)ρ0
[131] OTHERPKCONSSN←(C,A)ρ0
[132] OTHERPKCONVP←(C,A)ρ0
[133] REFCONFPINDEX←Cρ0
[134] URGAREA←(U,UL)ρ0
[135] URGAUXQTY←(U,UL)ρ0
[136] URGEND←Uρ0
[137] URGESCQTY←(U,UL)ρ0
[138] URGEXP←((S×U),7)ρ0
[139] URGEXPLOSS←((S×U),7)ρ0
[140] URGFPSCORE←(U,4)ρ0
[141] URGSCREEN←(U,3)ρ0
[142] URGSKED←(U,D)ρ0
```

```
[143] URGSSNQTY←(U,UL)ρ0
[144] URGVPQTY←(U,UL)ρ0
[145] OTHERPKURGAUX←(U,A)ρ0
[146] OTHERPKURGESC←(U,A)ρ0
[147] OTHERPKURGSSN←(U,A)ρ0
[148] OTHERPKURGVP←(U,A)ρ0
[149] REFURGFPINDEX←Uρ0
[150] BGAREA←(B,BL)ρ0
[151] BGCVQTY←(B,BL)ρ0
[152] BGEND←Bρ0
[153] BGESCQTY←(B,BL)ρ0
[154] BGEXP←((B×S),7)ρ0
[155] BGEXPLOSS←((B×S),7)ρ0
[156] BGFPSCORE←(B,4)ρ0
[157] BGSCREEN←(B,3)ρ0
[158] BGSKED←(B,D)ρ0
[159] BGSSNQTY←(B,BL)ρ0
[160] BGVPQTY←(B,BL)ρ0
[161] OTHERPKBGCV←(B,A)ρ0
[162] OTHERPKBGESC←(B,A)ρ0
[163] OTHERPKBGSSN←(B,A)ρ0
[164] OTHERPKBGVP←(B,A)ρ0
[165] REFBGFPINDEX←Bρ0
[166] DAYOFF←0
[167] PAUSE←0
[168] 'ALL INPUT VARIABLES HAVE BEEN SHAPED ACCORDINGLY.'
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